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PRELIMINARY DESIGN CONCEPT AND BUDGETARY COST FOR MINUTE MELTER AND CONTINUOUS MELTER AUTOMATED CONTROL SYSTEMS

Honeywell Corporate Program Center
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MUNITIONS TECHNOLOGY DIRECTORATE
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Letter on file

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20. ABSTRACT (CONTINUE ON REVERSE SIDE IF NECESSARY AND IDENTIFY BY BLOCK NUMBER):

Under the U.S. Army's Munition Plant Modernization Program several automated, remote control explosives melting and pouring processes are under consideration. These include the "Minute Melter" and the "Continuous Melter" approaches for use in loading 81 and 105 mm H.E. projectiles with Composition B explosive. The scope of this study covered the definition of the two explosives melting processes and conceptual design of automated process control systems for use in upscaled production facilities. Using information from existing pilot plant operations, process flow diagrams were prepared. to 1473B

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From these instrument flow diagrams were derived. Based on considerations of throughput capacity, safety, and reliability, a control scheme for automated operations of the two explosive melting processes was conceived and laid out diagrammatically. The associated control instruments, process control computers, and auxiliary devices of the control system are listed, together with cost estimates for each of the two melter process implementations. The design concept and budgetary cost estimates are preliminary, based on existing information, and prepared within the time and funding constraints of the contract.

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SECTION I

INTRODUCTION

For almost a century now, artillery shells have been loaded using the batch process for melting and pouring of the explosive fill. As part of the Munitions Plant Modernization programs of the United States Army, continous-process approaches for melt/pour operations have been investigated.

One of these has resulted in the establishment of the Picatinny Arsenal Continuous Melt/Pour Pilot Plant, including automated remote-control operation. The Picatinny Arsenal Continuous Melter operations have produced valuable results which serve as the specification foundation for modernizing Lone Star Army Ammunition Plant's Melt/Pour facility. Another approach for explosive "flake" as well as riser material melting is represented by the Minute Melter approach pioneered at Milan Army Ammunition Plant, and currently under evaluation at the prototype plant stage, but as yet without an automated remote control system.

The present study was authorized by Picatinny Arsenal under contract DAAA21-75-C-0175 to perform a design and cost breakdown for the process control automation schemes to be used for full-scale (production) melting plant operations (9000 lb/hr of Comp B. explosive) using either the Continuous Melter or the Minute Melter concept. NOTE: This study is limited to the melting portion of the loading process to permit analysis of automation of that phase of the process. The continuous melt/pour process described in this study has been limited to the part which receives explosive material and melts it.

Since neither plant has been established at full scale, and since the Milan plant is still undergoing development and evaluation in the present study, a number of assumptions will be made in order to arrive at conceptual process control systems for either process, based on the information now available to the present investigators.

Nevertheless, based on the reported characteristics of the undergoing processes, certain approaches for their instrumentation and control at the full-size plant level can be identified in sufficient detail to derive therefrom control systems for each and cost them out within the accuracy limits associated with budgetary system cost estimates.

Consistent with the information at hand, the rest of this report provides process descriptions, concept approaches for control, and a process control system with budgetary cost estimates for each of the two melter systems: Minute Melter and Continuous Melter. Section IV highlights our findings in the form of conclusions and recommendations.

SECTION II

MINUTE MELTER

The Minute Melter is a process based on melting one hundred-twenty (120) pounds of explosive at a time, relatively fast, so as to achieve high production throughputs. The Minute Melter is designed to handle Composition B explosive "flake" and riser scrap materials, or a combination of both "flake" and "risers" in the same melt.

The Minute Melter process has undergone evolutionary changes and refinements, which are still continuing. This section covers Honeywell's understanding of the present prototype plant equipment, its operation, and the current control scheme from which we will derive an automatic control system and cost estimate.

EQUIPMENT USED WITH MINUTE MELTER PROCESS

The basic equipment associated with the Minute Melter process is schematically depicted in Figure 2-1, and consists of the following:

1. feeder hoppers for manually introducing into the system
   a) virgin Composition B in "flake" (or "peanut brittle") form, and
   b) riser scrap accrued during the melt/pour operations
2. interlocking hoppers for feeding "flake" pre-heating and feeding of risers, respectively, into the melter proper
3. the Minute Melter for melting the explosive by the addition of live steam; and

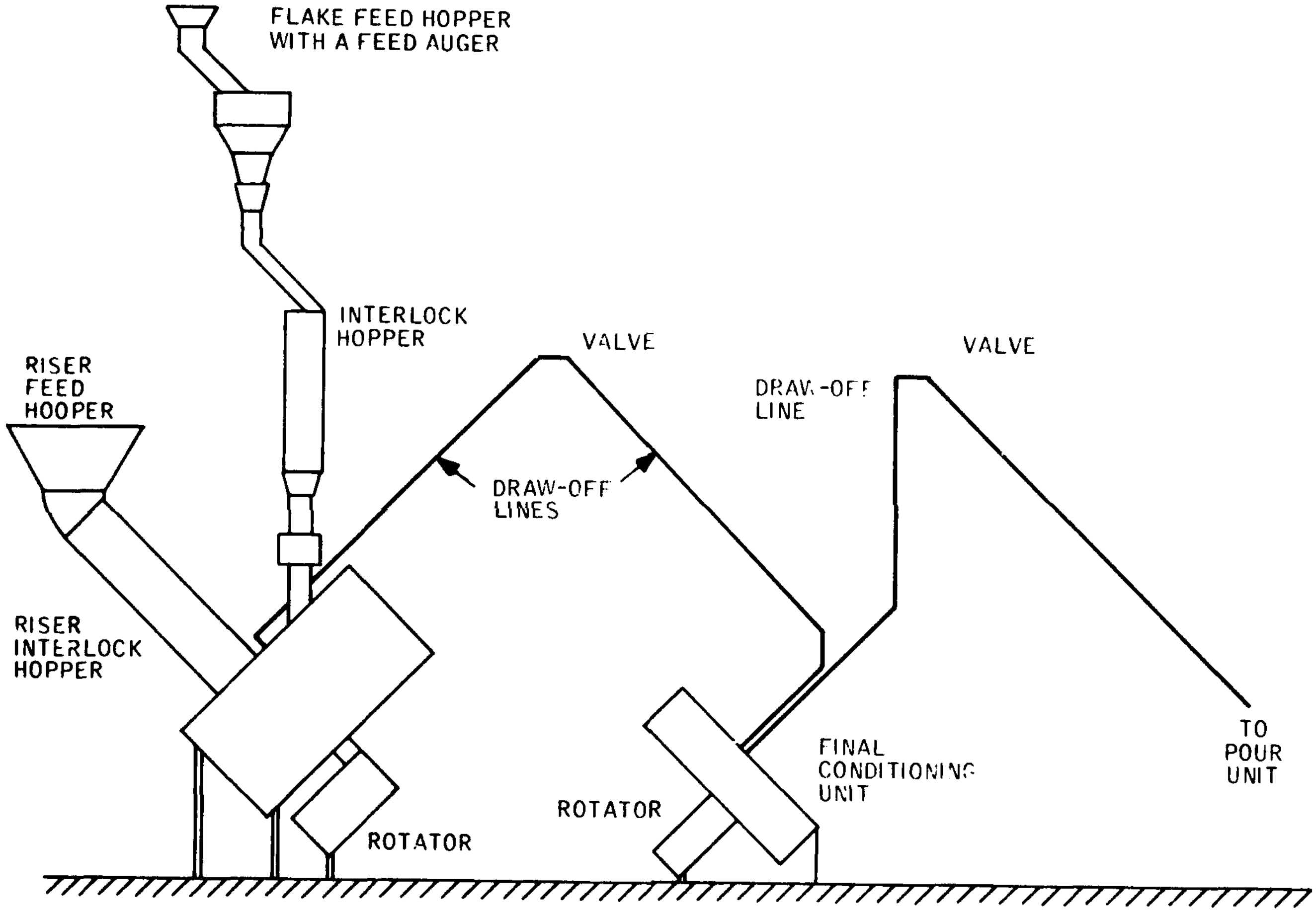

Figure 2-1. Simplified Process Equipment Schematic

4. two Final Conditioning Units for removing moisture from the molten explosive to pouring equipment. (The loading equipment is not part of this study.)

Associated with these pieces of basic equipment are the process required utilities, jacket heating and processing steam, hot water, pressurized air for explosive feeding, and vacuum pumps for moisture removal from the molten explosive, plus the associated jacketed pipes, valves, condensate traps, and auxiliary equipment, such as drive motors for the melter, conditioners, and the auger in the "flake" feeder.

The controls associated with the prototype minute matter consist of various sensors (temperature, pressure, and level), switches, and timers which in turn actuate control valves, dump valves, etc. These sensors and controls are not necessarily those required for remote automatic operation of a production facility utilizing the Minute Melter process.

The Minute Melter prototype plant process characteristics identified during discussions with knowledgeable personnel at Picatinny Arsenal have been entered in matrix format in Table 2-1.

Table 2-1. Milan Minute Melter – Existing Pr

	Jacket Heatant and Pressure	Contact Medium and Pressure	Explosive Capacity (Max. Lbs)	Typical Charging Increment (Lbs.)	Melt Temperature (°F)	Typical Batch Residence Time	Temperature Sensor		Pressure Sensors		Level S
							Jacket	Product	Jacket	Product	High
Flake Feeder Hopper	None	Ambient Air	120 lbs. Comp B Flake	2 boxes 120 lbs. Comp B Flake		5 sec.	None	None		None	None
Flake Interlock Hopper	Steam	Air, 14 psig	120 lbs. Comp B Flake	2 boxes 120 lbs. Comp B Flake		1 sec.	None	Thermo-couple	Gage	None	None
Minute Melter	Steam, 18 psig	Steam, 15 psig	350 lbs. Comp B (Incld'g. 175 lbs. "Heel")	120 or 51.5 lbs. Comp B (For 81mm shell)	240°F	42 sec.	None	None	Gage	Mannon-meter	Paddle(2) (For high Molten & High Solid Explosive Level)
Draw-Off Line	Steam, 18 psig	Steam, 15 psig	1 1/2 in. ID				None	None	Gage	None	
Final Conditioner (2)	Steam, 8 psig	Vacuum 25-26 in. Hg. & Air 5-15 psig	175	170 lbs. Molten Comp B (Enter @ approx. 240°F)	(25-26 in. Hg) Demoisture Pour Draw-Off at 185°F	90 sec. (Nom.)	None	Thermo-couple	Mannon-meter	Trans-ducer Graph Indic.	Mech ical
Draw-Off (Pouring) Line	Water, 190°F	Air 15 psig	1 1/2 in.		Approx. 185°F		Gage	None	None	Mannon-meter	
Riser Feeder Hopper	None	Ambient Air	51.5	51.5 lbs Comp B	None						
Riser Interlock Hopper	Steam, 10 psi	Steam, 15 psi	51.5	51.5 lbs Comp B	Preheat	103 sec.		None	Gage	Mannon-meter	None

- Existing Prototype Installation

e Sensors	Level Sensors		Rotation Speed Sensors	Flow Sensors	Product Flow Control Valves		Auxiliary Equipment	
Product	High	Low			Infeed	Outfeed		
None	None	None		None	None	Part of Interlock Hopper	None	
None	None	Photo-Electric Eye	None	Flapper	Flapper (Air-Operated)	Flapper (mech)	Screw-type Auger (Air-Powered	
Mannon-meter	Paddle(2) (For high Molten & High Solid Explosive Level)	Paddle	@ 12rpm (Nominal) Range To 20 rpm		Flapper (mech	Diaphragm (In Draw-Off Line)	Contaminated Steam Condensate Tank With High/Low Level Floats and Release Valve(s)	Variable Speed Inner-Drum Rotator
None				None	Diaphragm	Diaphragm	None	
Trans-ducer Graph Indic.	Mechanical	None	@ 8 rpm (Nominal) Range To rpm		Diaphragm	Diaphragm (In Draw-Off Line)	Vacuum System Explosive Fume Collector (heated pipes)	Variable Speed Inner-Drum Rotator
Mannon-meter				Manual Diaphragm	Manual Diaphragm		None	
					None	Part of Interlock Hopper	None	
Mannon-meter	None	None		Flapper	Flapper Air-Oper.	Part of Interlock Hopper	None	

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PROCESS SEQUENCES

The sequence of process steps involved in feeding solid Composition B "flake" and risers to the Minute Melter and conditioning the molten explosive alternately in two units is suggesed by the simplified block diagram shown in Figure 2-2.

The ratio of "flake" to riser scrap that is utilized in the Minute Melter process depends on the particular projectiles being loaded. For 81mm mortar projectiles, this ratio involves two boxes of Composition B "flake" (120 pounds approximately) and 51.5 pounds of recovered riser material. This ratio is affected by the RDX/TNT content of the riser material and the amount of wax present. The proportion of virgin Composition B to riser scrap must be adjusted so as to satisfy the end item requirements. (This explosive blending problem is outside the scope of the present study.)

The basic process steps may be grouped into four categories:

- Flake Feeding
- Riser Feeding
- Explosive Melting
- Explosive Final Conditioning

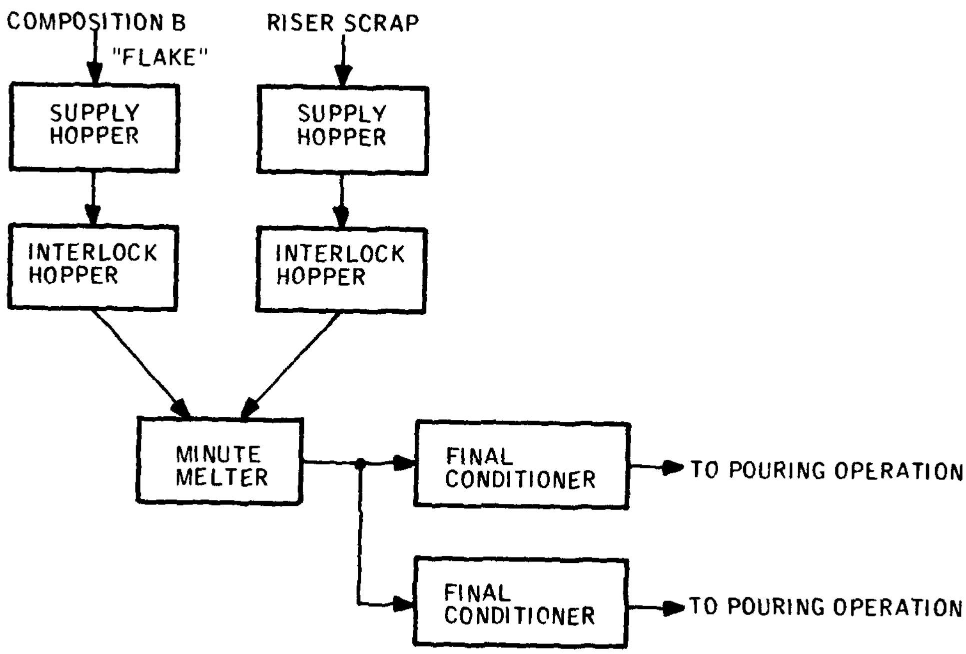

Figure 2-2. Simplified Minute Melter Process Block Diagram

The required throughput of 9,000 pounds of Composition B per hour in batches of two boxes of Composition B "flake" plus 51.5 pounds of riser scrap (equals 171.5 pounds total) per batch translates into 52.4 batches per hour or 68.5 seconds per batch (or roughly one batch per minute, as implied in the Minute Melter process designation).

EXISTING CONTROLS (Refer to Table 2-2)

The prototype plant configuration relies on manual loading of pre-weighed quantities of explosive flake and risers for weight and ratio control of the product entering the Minute Melter System. Some aspects of the process are under semi-automatic control, but the bulk of the valves, stop and start buttons, and other elements, are manually operated. Similarly, level indicators and pressure gages are visually checked by operating technicians. A simplified process instrument diagram is shown in Figure 2-3.

Given an experienced and alert crew, the plant operations can be carried out effectively. Care must be taken that the pressure of the steam contacting riser material and explosive directly does not exceed a safe level lest the explosive reach unsafe temperature levels. Also, if the rotating mechanism in the Minute Melter is stopped, contact steam pressure should be reduced to prevent overheating the explosive to critical levels. Also, if the rotating mechanism in the Minute Melter is stopped, contact steam pressure should be reduced to prevent overheating the explosive to critical levels. (These points are specifically listed also in the hazards analysis draft (Reference #1) that was provided as background for this study.)

Table 2-2. Basic Minute Melter Proces

Flake Feeding

Drop two boxes (120 lbs.) Composition B into Flake Feed Hopper.

Open upper flapper valve of Flake Interlock Hopper.

Transfer flake by gravity into Flake Interlock Hopper.

Close upper flapper valve of Flake Interlock Hopper.

Pressurize Flake Interlock Hopper by applying 15 psig air.

Start flake feeder auger feeder.

[When Minute Melter is ready...]

Open lower flapper valve of Flake Interlock Hopper.

Feed flake into Minute Melter under pressurized air.

Stop auger when photoelectric eye at bottom of Flake Interlock Hopper indicates all explosive has been transferred into Minute Melter.

Shut-off air pressure supply to Flake Interlock Hopper.

[Repeat explosive flake feeding cycle]

Riser Feeding

Drop 51.5 lbs. of riser scrap into Riser Hopper.

Open upper flapper valve of Riser Interlock Hopper.

Gravity feed risers into Riser Interlock Hopper.

Close upper flapper valve of Riser Interlock Hopper.

Heat risers using jacket heat and 15 psig injected steam.

[Assuming that Minute Melter is ready to accept next batch o and riser explosive, steam injection into Minute Melter is s draw-off valves are closed.]

Open flapper valve connecting Riser Interlock Hopper to Minu

Transfer riser explosive into Minute Melter using gravity and 15 psi steam injected into Riser Interlock Hopper.

Shut off steam injection into Riser Interlock Hopper.

Close flapper valve between Riser Interlock Hopper and Minut

Explosive Melting

[Assuming that flake has also been transferred into Minute M the corresponding flapper valve has been closed.]

Inject 15 psig steam into rotating Minute Melter.

Melt explosive flake and risers under agitation.

When high limit paddle sensor indicates molten explosive has draw-off level, open valve in draw-off line between melter an final conditioning unit.

Transfer molten explosive from Minute Melter through draw-off under the effects of 15 psig steam in Minute Melter.

Close draw-off valve when molten explosive level has sunk to in melter.

[Leaving only heel in melter.]

[Repeat explosive feeding and melting cycle.]

lelter Processing Steps

accept next batch of flake

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<u>Explosive Final Conditioning</u>

[Two units used alternatively.]

[After filling of Final Conditioning unit with the force of 15 psig steam in the Minute Melter, actual conditioning cycle starts when diaphragm valve in Draw-off Line from Minute Melter is closed.] Line from Minute Melter is closed.]

- Evacuate water vapors from explosive being rotated in inner drum of Final Conditioning unit.

- When product temperature cools to approximately 178°F, turn off vacuum.

- Apply vacuum until product temperature drops to approximately 178°F or until vaporization stops and the product temperature rises. Turn off vacuum.

- Pressurize Final Conditioning unit to required psig with heated dry air.
- Open draw-off valve in Draw-Off Line leading to Pour Station after approximately 90 sec.
- Eject conditioned explosive with air pressure.
- Shut off air pressure when all explosive has been ejected from Conditioner.
- Close diaphragm draw-off valve.
- Repeat conditioning cycle.

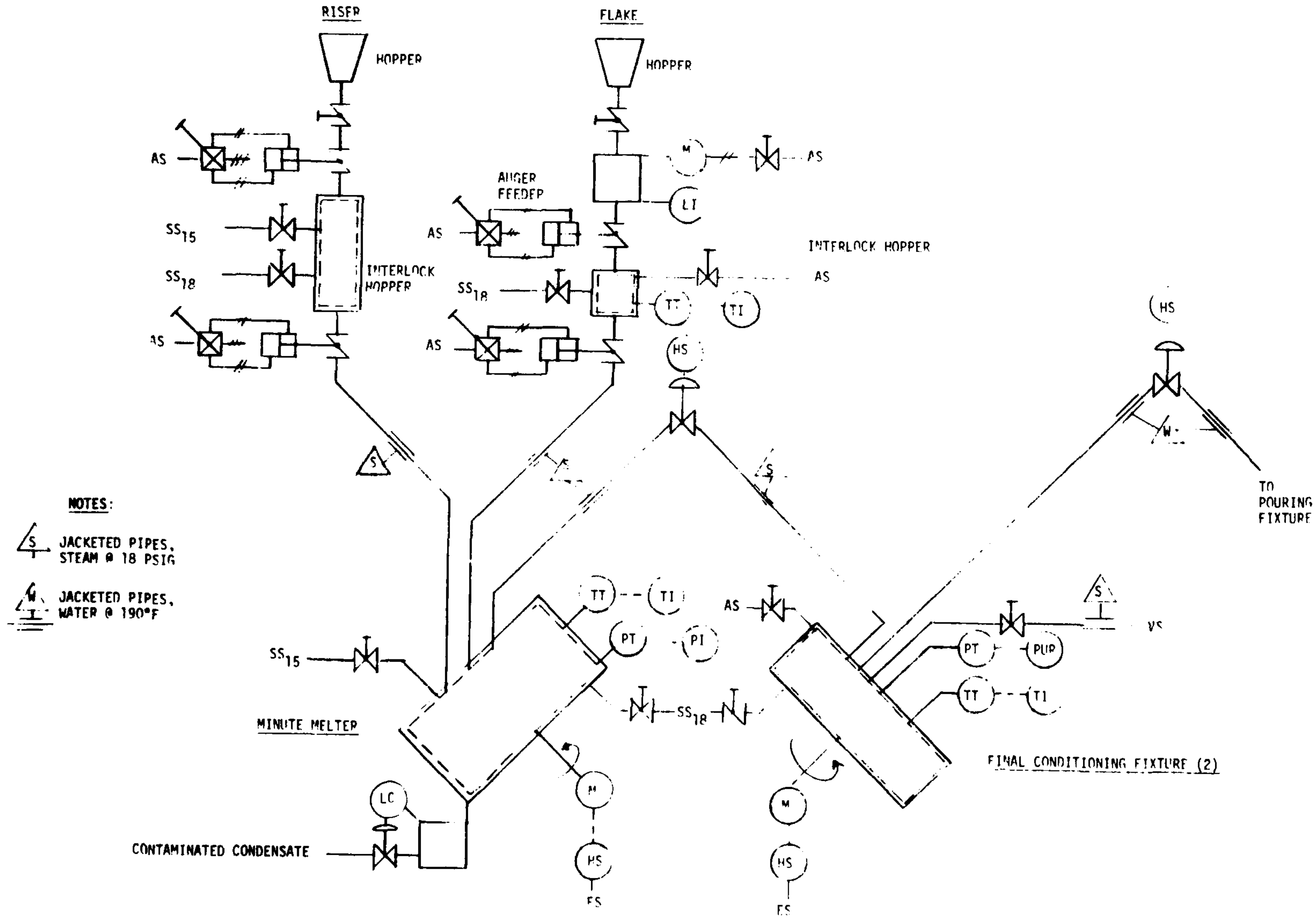


Figure 2-3. Process Instrument Diagrams for Milan Minute Melter Prototype

For remote control, automatic operations, however, additional instruments and controls will be required to place the entire system under computer control. Also, manual operations, such as explosive feed, apportioning, and ratio control will have to be mechanized and placed under computer control.

DESIGN APPROACH FOR AUTOMATIC REMOTE CONTROL SYSTEM

One of the primary design considerations for modernized melt/pour plant operations is to have no operating personnel directly exposed to the explosive material. This necessitates provisions for monitoring all process equipment from a remote location. This also requires the appropriate process control instruments and sensors to provide for:

- Melt/Pour Process Control
- Automatic Sequencing
- Operational Safety Monitoring
- Data Logging
- Operator Displays

Further, the control system for the Minute Melter operations must provide for the following operational modes of the plant:

- Startup
- Ready for Use
- Production Runs
- Normal Shutdown
- Emergency Shutdown

In each of these operational modes, system control must be provided for all process equipment, material handling devices, auxiliary equipment, and any fire protection or disaster control provisions incorporated into the facility.

To measure and maintain the conditions required for stable operations or to change conditions for each of the operational modes of the system as a whole requires that the control elements be configured into appropriate control loops. Some of these may be simple ON/OFF open loops, but others are interrelated with several process variables requiring multi-loop setups. Further, response characteristics in sensors and delays in the manipulated variable are affected by lags between measurement of a deviation and correction for this deviation due to dead time, actuation lag, and other characteristics. Therefore, many control loops must be configured as closed loops with feedback to compensate for process reaction rate, transfer lag, and process load changes. The mode of control for these various conditions is summarized in Table 2-3.

Table 2-3. Usage of the Various Control Modes

MODE OF CONTROL	PROCESS REACTION RATE	TRANSFER LAG OR DEAD TIME	PROCESS LOAD CHANGES
Two-Position	Slow	Slight	Small and Slow
Proportional	Slow or Moderate	Small or Moderate	Small
Proportional-Plus Rate Action	Slow or Moderate	Moderate	Small
Proportional-Plus Reset	Fast	Small or Moderate	Slow, but any amount
Proportional-Plus Reset-Plus-Rate Action	Fast	Moderate	Fast

The physical layout of the process and auxiliary equipment installed within the rooms and buildings of the melt/pour plant and the interconnected plant contains in juxtaposition the several instruments, sensors, and actuating devices needed to operate, control, and monitor the process equipments and their utility services. The interconnections between equipment, utilities, instruments, and sensors monitored remotely in the controol room comprises the control system that is the subject of the present study.

CONTROL SYSTEM ELEMENTS

In the prototype process the controlled variables of the process, such as the temperature of the molten explosive or the level of the explosive in the melter can be

determined using a suitable measuring instrument. To bring the controlled variable to the desired level, the final control element, such as a steam valve, has to be opened or closed manually. The operator controls these actions and provides the feedback between observed measurement and actuation of the control element or its activator.

In automatic local control, the operator is replaced by an instrument (the "controller") that utilizes a sensor to measure the controlled variable and sends a signal to the actuator for the final control element to bring the process variable to the desired value.

Because of process load changes and process lags owing to capacitance, resistance, and dead time effects in the processing equipment, changes in the manipulated variables (e.g., steam pressure applied to the melter jacket) do not instantaneously bring the process variable (e.g., temperature of the explosive being melted) to the desired value. Thus, in order to prevent overshooting the set point and enhancing stability of the process, several modes of control should be considered for a given instrument loop:

1) Two-position
2) Proportional
3) Proportional plus Reset
4) Proportional plus Reset plus Rate

This requires utilization of feedback between measurement and actuation to achieve better control.

A variety of local automatic controllers is available for each of the control functions involved. These can be configured as electric or pneumatic devices, packaged within one housing or with the controller instrument mounted remotely from the process equipment and the measuring element.

The individual control loops are not truly independent, but interrelated. For example, either contact steam or jacket steam pressure may heat the explosive beyond desired limits, singly or in combination. Therefore, these control loops must be interlocked to assure safe operations.

Also, if power or air pressure used for control purposes should be interrupted, a given control loop must prevent the process variable from reaching unsafe conditions. This can be accomplished by either holding the last signal level or by reducing the affected manipulated variable to a lower safe level (fail-safe principle).

For remote, automatic operation of the Minute Melter system, a graphic representation, such as a panel, is needed in the control room for monitoring the various control loops.

Manual remote control of the system is impractical because of the large number of control loops. Local automatic control with remote monitoring and manual override is also difficult, owing to the numerous loop interlocks for safety's sake. Thus, a more powerful system control approach has to be employed, and this is direct digital control with local automatic control backup and manual intervention through the software channel in the control computer. In this arrangement, local instruments may be either of the

analog or digital variety, actuators may be either pneumatic or electric. Through proper signal processing devices, all of the measurement and control circuits can be manipulated in the proper manner with local backup and fail-safe conditions in mind.

All of these considerations enter into the selection of the individual controller for the various control loops and their interconnections with process equipment, utilities, and control room for efficient operations. Based on many years of involvement in control systems design, proven solutions to the problems at hand are made on the basis of safety, reliability, and costs, as described in the following section.

CONCEPTUAL MINUTE MELTER AUTOMATED CONTROL SYSTEM

To establish the requirements for the Minute Melter Automated Control System, a summary of the attendant safety constraints has been prepared and is included here as Appendix A. No modification of the process sequencing or control philosophy has been attempted (i.e., beyond the scope of this study). Sequence control as delineated in Table 2-2 is taken as the basis for the recommended automatic control system.

Automated process control is recommended for the Minute Melter Control elements, as shown in Figure 2-3. The Instrumentation List for this control interface configuration is included as Appendix B to this report. One addition, not shown, but necessary to achieve full automatic operation, is the feeding equipments that maintain the correct ratio of virgin flake to riser scrap material into the process. The recommended

equipment for this function is weigh feeders with mass-flow control.

Control system functions for this process are divided among the following major categories:

1) Automatic Virgin Flake/Riser Scrap In-Feed Ratio Control
2) Automatic Temperature Control of the Process Equipments
3) Automatic Sequence Control of the Process
4) Automatic Quality Control of the Final Explosive Conditioner Processing Equipment
5) Automatic Safety Monitoring and Control of the Minute Melter System
6) Automatic Remote Monitoring Data Logging, and Operator Control of the Minute Melter System

Implementation of the control system required to fulfill the six objectives identified above is shown in block diagram form in Figure 2-4.

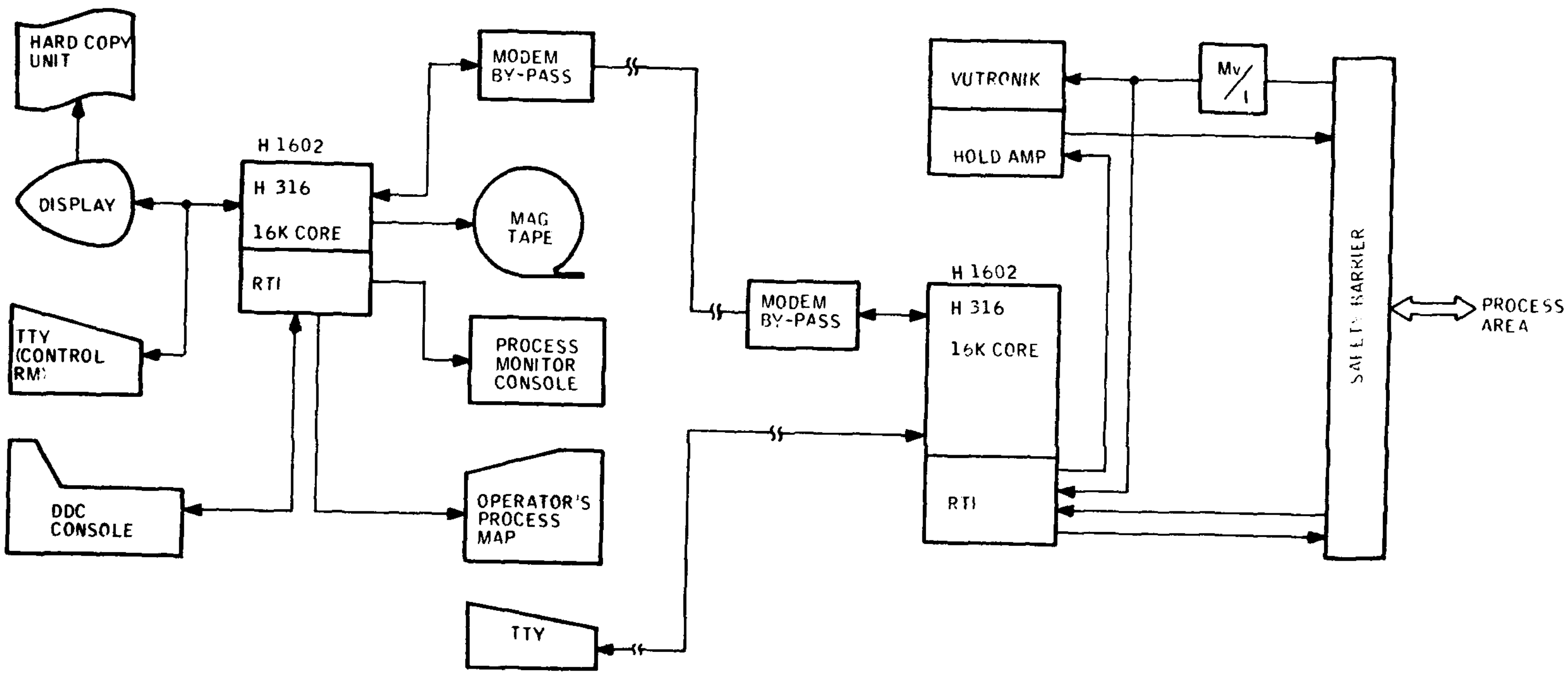


Figure 2-4. **Minute Melter Control System Configuration**

COST ESTIMATE FOR MINUTE MELTER CONTROL SYSTEM

To prepare an estimate of the cost for automating the Minute Melter System a tentative hardware list was established.

Table 2-4 is the delineation of equipments required for the process control computer. Table 2-5 is the list of the process control analog instrumentation.

The equipment list for the process monitor system is included as Table 2-6.

Cost estimates for these equipments and services are as follows:

1)	Systems Engineering	$ 55,600
2)	Software Development	90,000
3)	Process Control Computer Equipment	37,000
4)	Process Control Analog Equipment	24,000
5)	Process Control Equipment Installation	8,600
6)	Process Control Interface Wiring	13,500
7)	Intercomputer Communication Wiring	3,500
8)	Process Monitoring Equipments	55,000
9)	Process Monitoring Equipment Installation	6,500
10)	Total System Debug and Demonstration	42,800
	TOTAL	$336,500

Table 2-4. Minute Melter Process Control Equipment List

QUANTITY	MODEL	DESCRIPTION
1	1602-01	H1602 Real Time Control
3	1602-02	Additional 4K Core Modules
1	316-0800	Base Sector Relocation
1	316-6000	Data Line Controller
1	316-6006	DMC Sub-Channel
1	1602-11	High Speed Arithmetic
1	1602-6925	Modem By-Pass
1	316-20	Direct Multiplex Control
1	1621-07	Cyclic Redundancy Check
1	1602-8611	Analog Master Page A
2	1602-8642	MUX, High Level Differential
2	1602-8641	MUX, Low Level Single Ended
3	1602-8634	MUX, Low Level T/C
1	1602-8676	Isothermal Units, 30 T/C Inputs
1	1602-8653	Amplifier, 100 mv
1	1602-8657	Amplifier, 10 v
2	1602-8581	Customer Connections, Analog
3	1602-8731	Status Inputs PACs (contact)
1	1602-8811	DDC Station Controller
3	1602-8831	Power Flip-Flop
1	1602-8861	Relay Output Module
1	1602-8721	+24V, 6A Power Supply
3	1602-8580	Customer Connections, Digital
1	1602-8761	Event Counter
1	1602-8741	Async Input PAC, Contact
1	1602-8541	Watch-dog Timer and #1 Timing Chain

Table 2-5. Minute Melter Process Control Analog Equipment List

QUANTITY	MODEL	DESCRIPTION
8	36686-3063-0100-512-000-51	VutroniK DDC Stations
6	36689-3063-0100-000-51	VutroniK Stations
10	39511-4060-111-51-72	MV/I Transmitter
1	38582-2010-0000-000-72	Power Supply, 7-amp.
2	37800-2060-0000-000-000-72	Multi-Unit Case
42	38545-0000-0110-111	Barrier Points, Positive
42	38545-000-0110-112	Barrier Points, Negative
20	ELA 3271	Kent Barriers

Table 2-6. Minute Melter Process Monitor System Equipment List

QUANTITY	MODEL	DESCRIPTION
1	1602-01	H1602 Real Time Control System
2	1602-02	Additional 4K Memory Modules
1	1602-6925	Modem By-Pass
1	1602-11	High Speed Arithmetic Module
1	316-6000	Data Line Controller
1	316-6006	DMC Sub-Channel
1	1602-20	Direct Multiplex Control
1	1621-07	Cyclic Redundancy Check Module
4	1602-8580	Customer Connection, Digital
1	316-5303	ASR-33 TTY With Interface
2	1602-8851	Universal Output Flip Flop PAC
3	1602-8732	Status Input PAC
1	1602-8852	Universal Output Single Shot PAC
1	1602-8831	Power Flip Flop Output PAC
1	1602-8742	Asynchronous Input PAC
1	1602-8721	+24V Power Supply
1	1602-8541	Watchdog Timer and #1 Timing Chain
1	96-02-02	DDC Operator's Console
1	Special	Operator's Process Map
1	Special	Process Monitor Console

SECTION III

CONTINUOUS MELTER

The Continuous Melter process was developed at Picatinny Arsenal as replacement for batch processes currently used in melt/pour operations at Army Ammunition Plants.

DESCRIPTION OF CONTINUOUS MELTER PILOT PLANT

Picatinny Arsenal developed and installed a pilot scale plant of a production-sized projectile loading plant. The pilot plant has a processing capacity in excess of 1,000 pounds/hour of Composition B flake explosive, and also has the flexibility to melt other explosives, such as Amatex. The equipment in the pilot plant, as originally conceived, is shown in Figure 3-1 together with its Instrumentation Control and Monitoring System (ICMS). The ICMS is a computer-based automatic process control system tailored to meet the requirements of the pilot plant.

EQUIPMENT

The pilot plant is housed in several buildings at Picatinny Arsenal. (See Figure 3-2.) The major pieces of equipment include the following:

- Feed Conveyor, including pre-heating of Composition B flake
- Feed Hopper
- Weigh Feeder

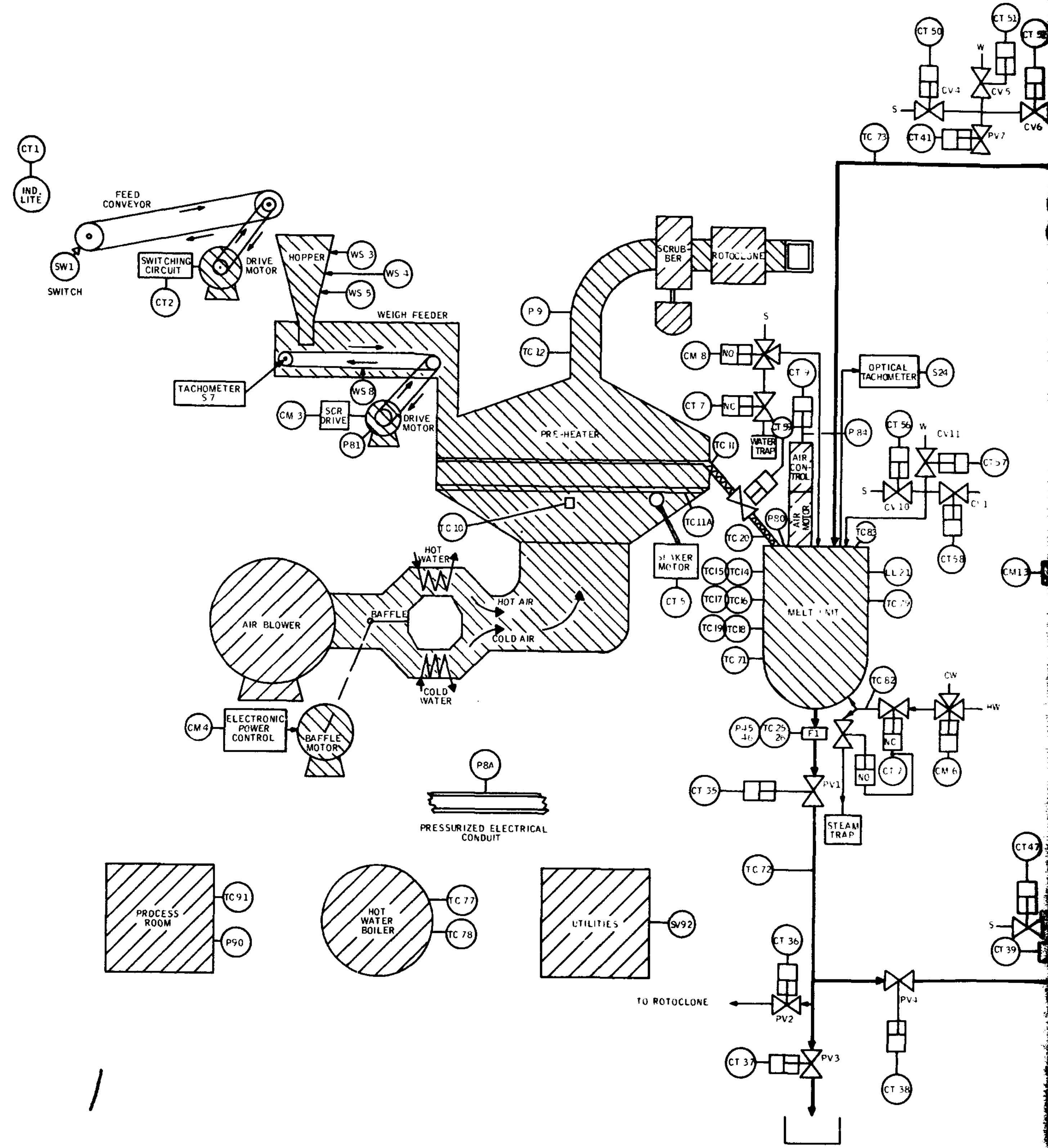
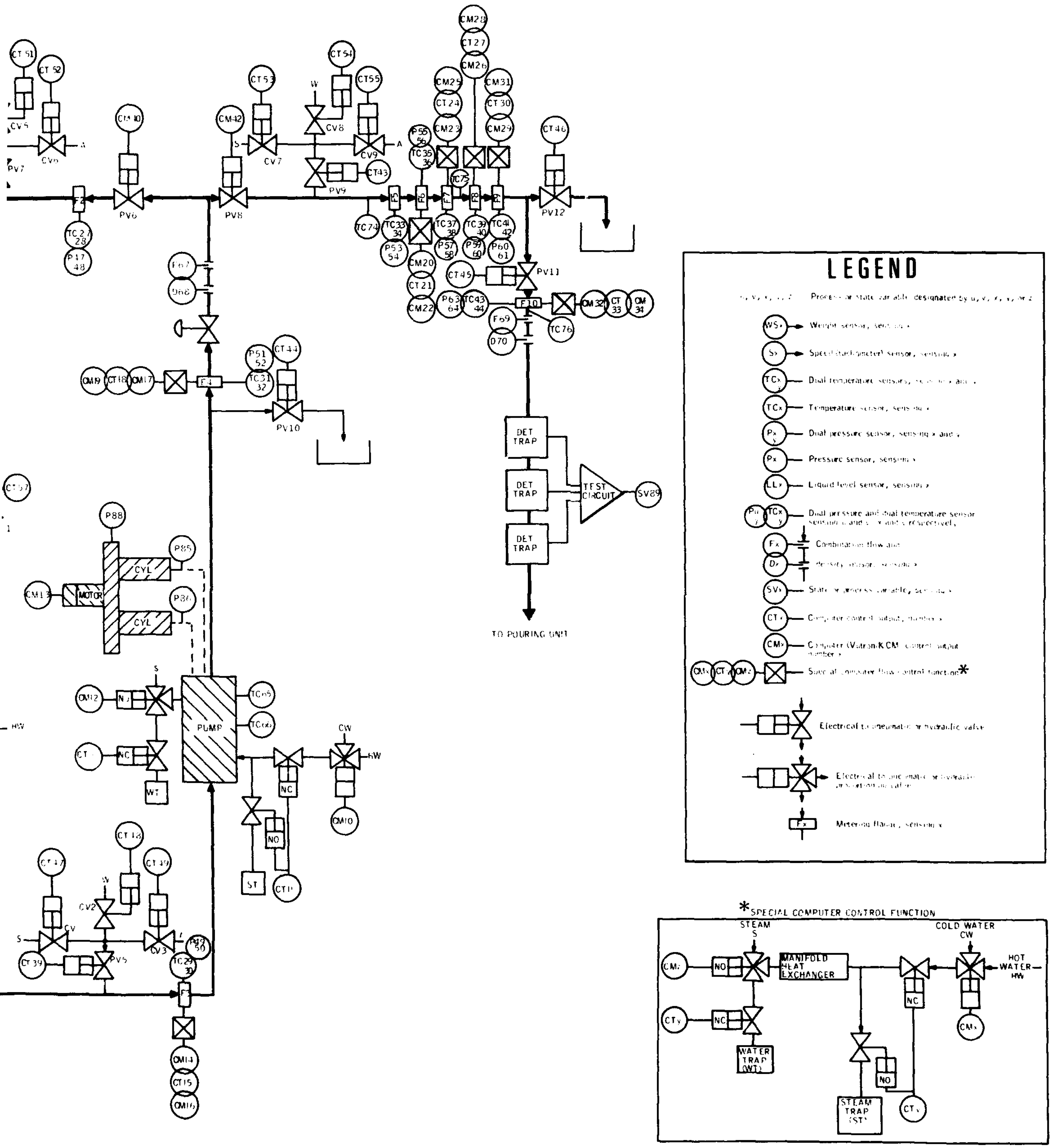


Figure 3-1. Continuous Me


LEGEND
Pressure sensor
Electrical
*SPECIAL COMPUTER CONTROL FUNCTION
STEAM
S
COLD WATER
CW
HOT WATER
HW
MANIFOLD HEAT EXCHANGER
WATER TRAP (WT)
STEAM TRAP (ST)
NO
NC
DET TRAP
DET TRAP
DET TRAP
TEST CIRCUIT
SV89
TO POURING UNIT
PUMP
MOTOR
CYL
CYL
PV6
PV8
PV9
PV10
PV11
PV12
CV7
CV8
CV9
CV2
CV3
PV5
P88
P85
ST
WT

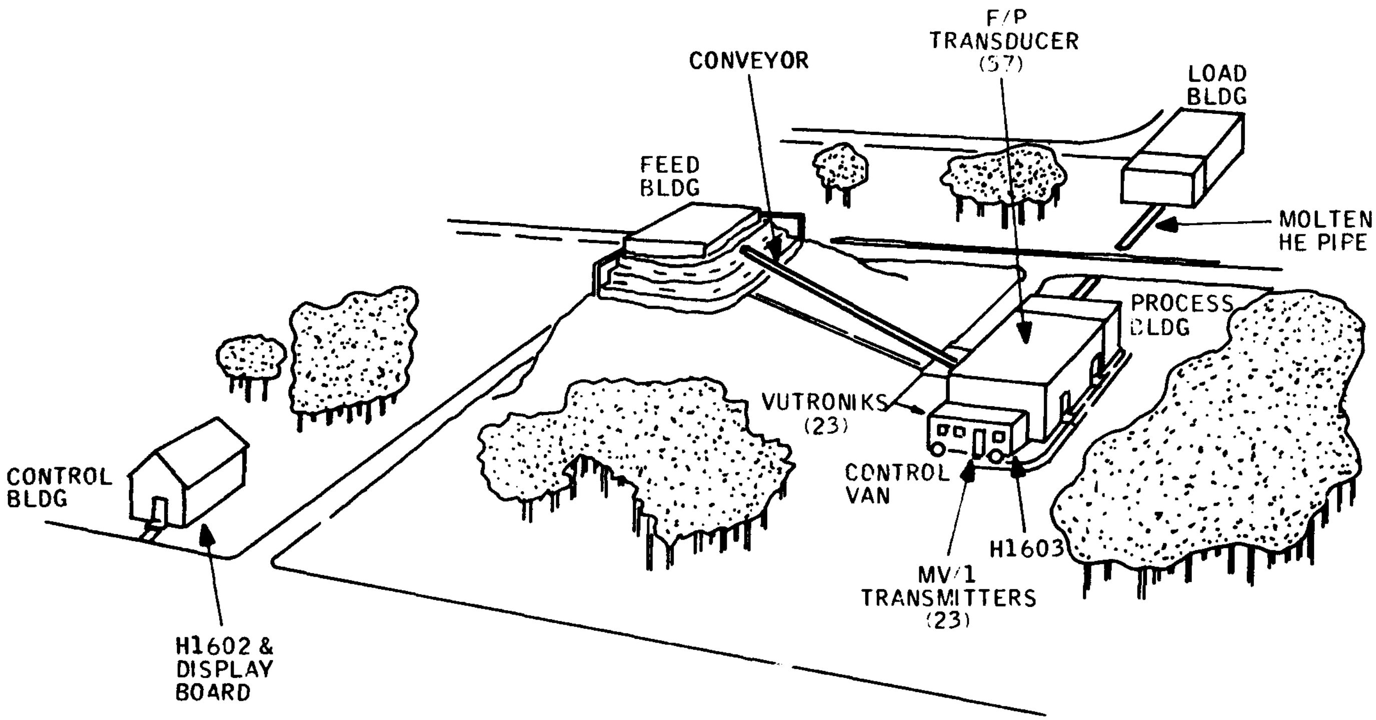


Figure 3-2. Continuous Melt/Pour Pilot Plant

- Melt Unit
- Explosive Pumps
- Explosive Valves and Piping

The installation also includes utility valves and pipes, surveillance TV equipment, and the monitoring display in the control room. Since the existing plant equipment is documented elsewhere, further details will not be duplicated here.

CONTROLS (ICMS)

In accordance with the safety objectives for the pilot plant to exclude all personnel from direct exposure to explosives, the total process is automated. The control room is approximately 1,200 feet removed from the melter building. The ICMS is configured to accommodate the pilot plant layout. The individual elements of the control system are also shown schematically in Figure 3-1.

The general configuration of the ICMS in block form is shown in Figure 3-3. The H1603 Real-Time Computer System that interfaces with analog and with digital instruments is housed in a separate compartment (van) outside the melter building. It is connected by a communications link to an H1602 Real-Time Computer System in the control room. This computer system interfaces with the operator's console and the computer input/output devices, and performs data logging and graphic display data processing.

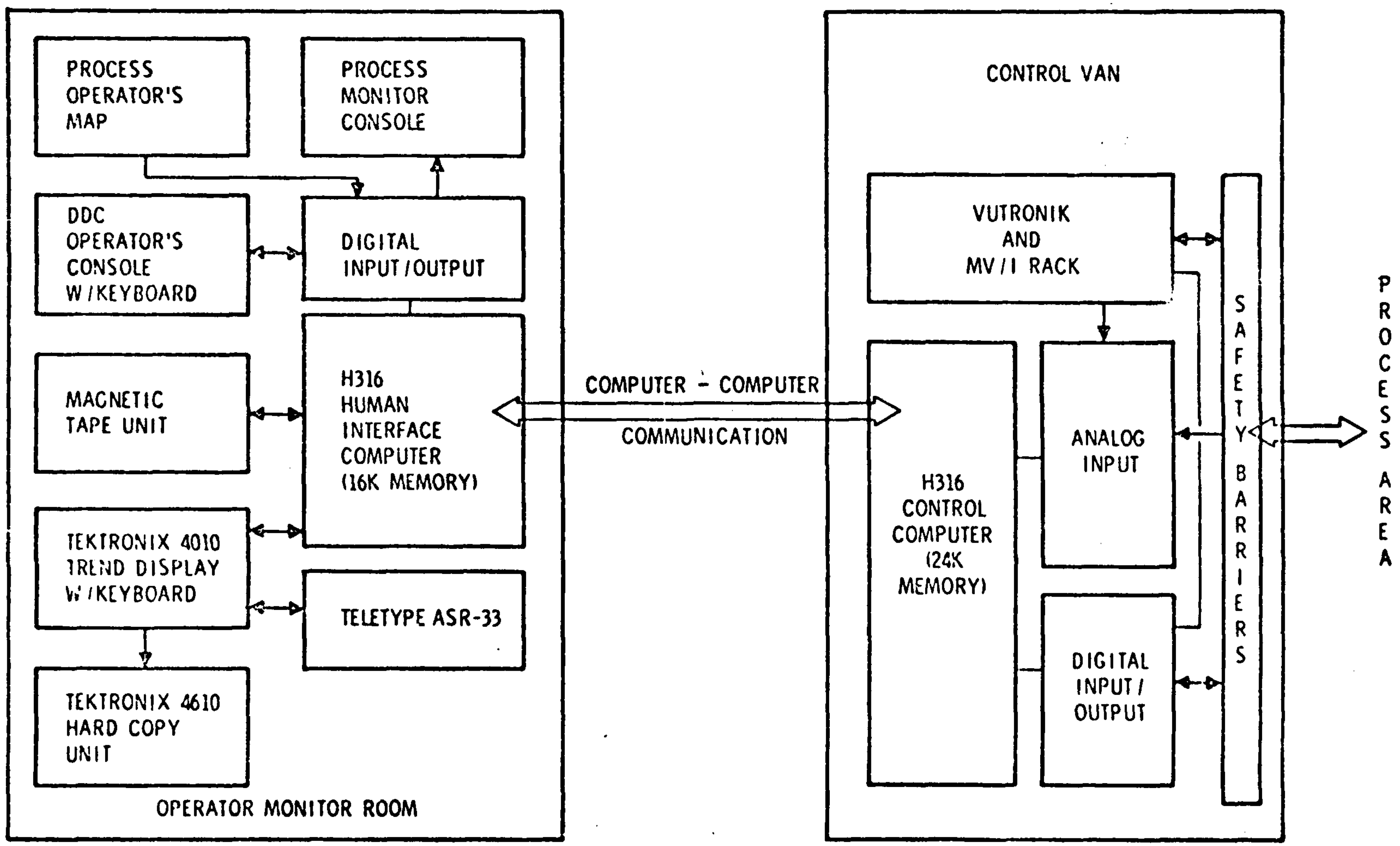


Figure 3-3. Continuous Melter System Control System Elements

More than 50 analog sensors inputs and 32 on/off signals are monitored as process data. Forty-eight digital outputs and 25 proportional outputs are sent to the process equipment in order to achieve closed-loop control of feeding, heating, melting, agitation, pumping, etc.

The instrumentation and monitoring system functions include:

- Automatic Startup and Shutdown - The ICMS controls the sequencing of the pilot plant operation during startup and shutdown modes. These programs, like many other ICMS design features, are established to limit the system operator from repetitive tasks and prevent the possibility of error.

- Melt/Pour Plant Continuous Process Control - The process is automatic during the continuous "Run" using the computer-based DDC. Backup control is provided by automatic setpoint control in the analog stations. Manual override is commanded through the Operator's Console.

- Operational Safety Monitoring - Status of safety sensors for fire, deluge water, utilities, etc., is monitored continuously for proper settings. Process parameters, including explosive temperatures, flow rates, and levels, are monitored. Variable data are compared to preset limits, and safety override actions are commanded when the variables reach the limits.

- Data Logging - The ICMS provides the capability (operator-selectable) to record all data from the pilot process on magnetic tape. The data is logged, each at operator-selected interval (normally 15 seconds). Operator commands and safety limit outputs are also recorded on the magnetic tape. All log entries are identified with their point of origin and their time of occurrence.

- Operator Displays - A graphic display map panel is part of the ICMS. This gives the process engineer a quick assessment of the complete melt/pour process status. This panel displays the critical process sensor values, in digital form, updated every 15 seconds. A second graphic output is provided by a CRT on which any of the process variables may be plotted in real-time. This is especially useful for pilot plant developmental work.

- Operator Switch Panel - This panel is equipped with switches for the process operator to initiate the automatic computer programs. Switches are also included for manual operation of process valves and certain equipment functions.

Status of the process is transmitted each data logging interval (normally 15 seconds) to the Control Room. There it is simultaneously displayed on the graphic console and recorded on nine-track digital magnetic tape. Alarm conditions are monitored continuously, and visual displays of problem areas, as well as impending problems, are annunciated.

Tuning of control loops, modification of control loops, and other operator interventions are done through the Operator's Console or the Computer I/O device in the Control Room. Program image storage and refreshment of both computers is achieved via magnetic tape to computer-core data transfer programs and down-line loading to the H1603 (in the Instrumentation Van).

Particular emphasis has been placed on operational mode control programs and safety override programs. Operating modes ranging from total operator control to total automatic control for all states from "System Ready for Use" through "Startup," "Run," and two types of "Shutdown" have been developed to allow all the variations possible in a pilot plant operation. Operational safety is assured by special programs and system design. Variable signals are monitored and their value compared to preset limits. If the variable meets or exceeds the limit, then overriding action is taken to correct the situation. Also, the computer monitors itself to assure that it has not halted. If a halt is detected, the ICMS goes to a fail-safe condition, and a message is given to the operator in the Control Room.

The ICMS for the pilot plant was configured to serve as an R & D tool, as well as the operating control system, during actual explosive melting trials. As such, it incorporated a number of features that may not be required for a production plant without an R & D mission. The insights gained from the ICMS design, installation, and operating experience are reflected in the design approach taken in configuring an automatic control system for a full-scale loading plant. These considerations are covered in the following sections.

CONCEPTUAL DESIGN APPROACH FOR AUTOMATED PRODUCTION SCALE CONTROL SYSTEM

Figure 3-4 shows the basic Continuous Melter Process. This system performs similar functions to the Minute Melter, i.e., it automatically feeds in flake explosive, melts the flake, and delivers the molten explosive to a downstream process for pouring or whatever is chosen to be done as the next step. The Continuous Melter equipments and controls are not as complex as those to which they correspond on the Minute Melter, primarily due to the omission of the raw riser scrap feeding function for the Continuous Melter. Also, the equipment and controls for the Continuous Melter Process are simplified by the omission of demoisturizing function. Remote purging of the Continuous Melter Process equipments is a function included in this subset. Even though remote purging does not correlate to a similar feature for the Minute Melter, it does carry out the theme of minimizing direct personnel exposure to the explosive in process.

Functional areas for the Continuous Melt Process and their control-related means are identified in the following paragraphs:

1) Feed Conveyor and Hopper - This includes the belt conveyor which carries the flake explosive from the Inspection Building to the Melt/Pour Building (a second function, i.e., preheating the explosive flake, is implemented during this conveying of material; it will be described next) and the explosive flake receiving hopper in the Melt/Pour Building.

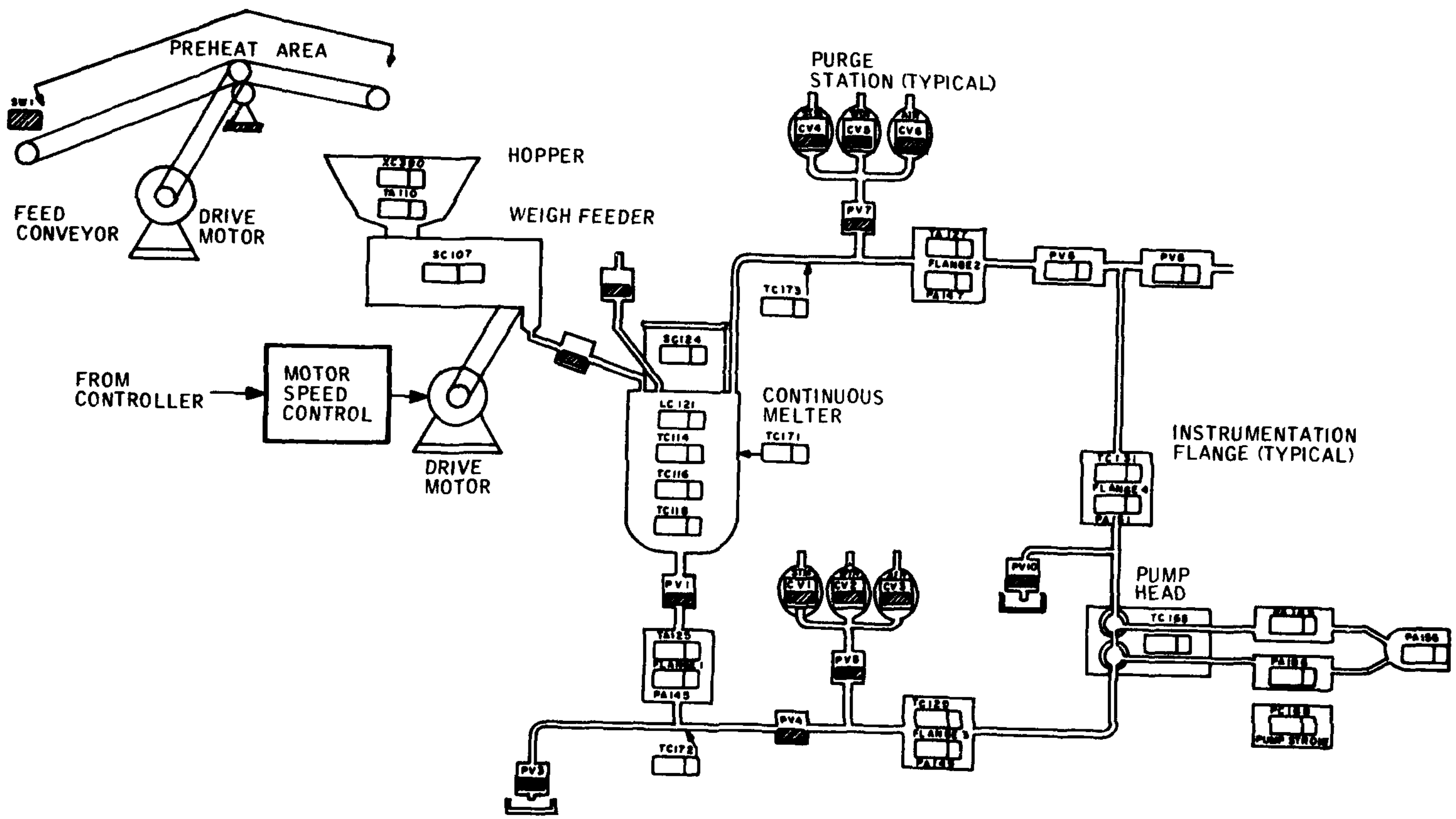


Figure 3-4. Continuous Melter Subset with Controls

The objective of this functional area is to automatically maintain a supply of flake explosive material in the hopper ready for use in the melting process and to tolerate full range fluctuating demands for the stored material. To accomplish this objective, a closed loop control of the feed conveyor was implemented using the surge bin hopper net weight as the process variable. (See Figure 3-5.) A material height in the hopper versus net weight correlation was established in the control system, thus permitting the operator to select the minimum material height where the conveyor will be started and the maximum material height where the conveyor will be stopped. An embellishment incorporated in this Feed Conveyor - Hopper Loop is the hopper-weighing configuration.

This hopper is supported by load cells at three points. The output of each load cell is brought back to the control computer, and each cell output is evaluated per its own calibration curve. The embellishment comes from the manner in which these three outputs are handled. Normally, the output is summed to determine the net weight (the tare is zeroed out via excitation null adjustment), and the summed weight is converted into the material height process variable. An automatic reasonableness test is made on each cell output and, if any one of the three cells is giving an unreasonable signal, that signal is dropped, the material height is calculated on the signals from the other two, and the

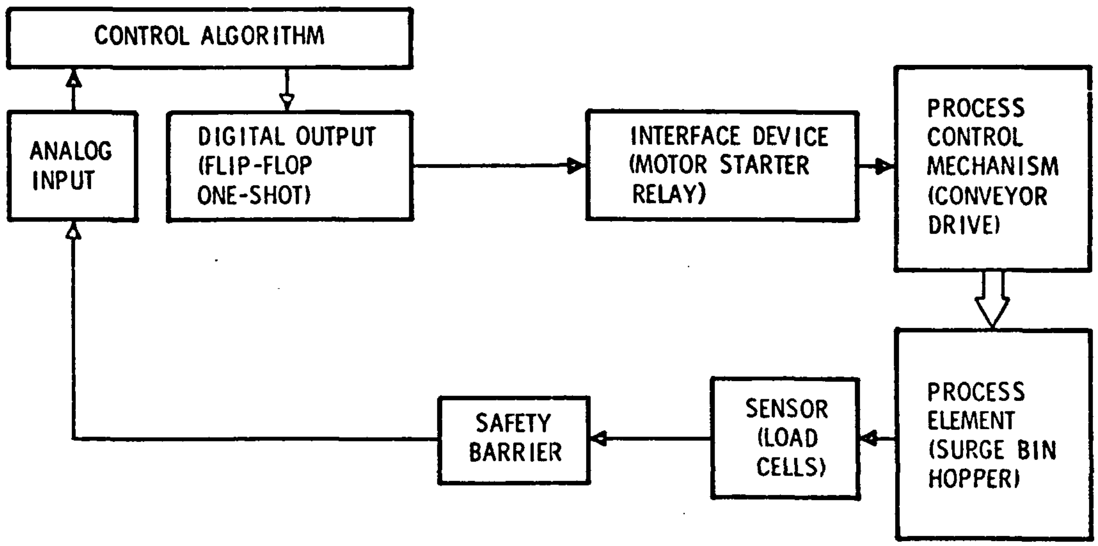


Figure 3-5. Belt Feed Conveyor Control

operator is alarmed. If a second cell gives an unreasonable signal value, then the process is stopped, and the operator is alarmed.

2) Preheating of the Explosive Flake - This is accomplished while the material is being conveyed between the Inspection Building and the Melt/Pour Building. The steam-heated radiators are located in the protective shroud which covers the conveyor between the two buildings.

Closed loop control of the preheating process is accomplished, as shown in Figure 3-6, by measuring the process variable (operating temperature as indicated by TC-12), and adjusting the steam control valve per a three-mode algorithm. A backup check is made of the temperature of the explosive as it is stored in the surge bin hopper. N‹ control is derived from this second check; only operator alarming, if the measured temperature goes beyond preset limits.

3) Weigh Feeder Speed Control - Melt Unit Level Control

This is the most complex functional area of the Continuous Melter Control System. The melt unit is equipped with a capacitance type liquid level probe to measure the distance fromthe surface of the explosive material to a reference surface (i.e., the top of the melt unit tank). The weigh feeder equipment includes a controllable, variable speed drive and a material mass-flow sensor whose output indicates the pounds/minute the unit is delivering. The purpose of these equipments is

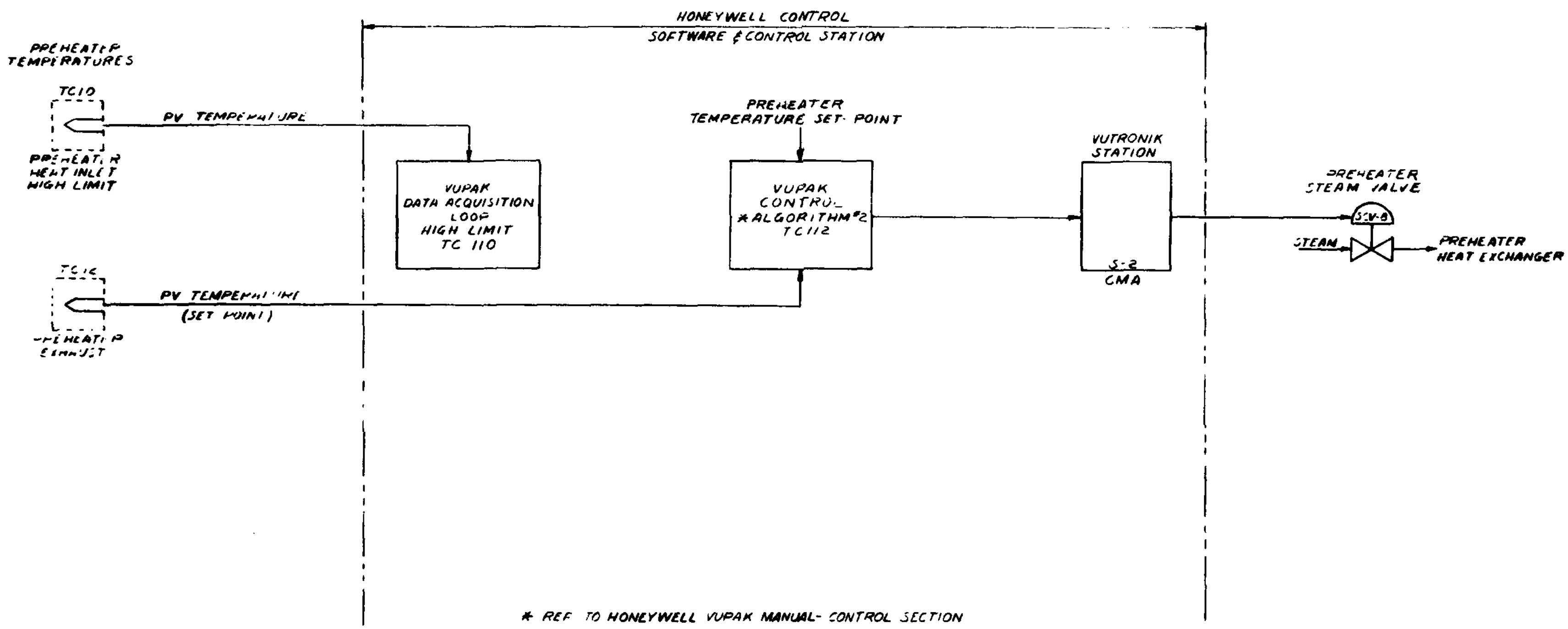


Figure 3-6. Pre-heater Temperature Control

to keep the melt unit filled with flake explosive to a level of five (5) inches from the top, thus maximizing its efficiency while operating safely.

Control of the Melt Unit Fill Level loop is achieved as indicated in Figure 3-7. The primary process variable is measured by sensor LC-21. This signal is compared to the Melt Unit Level setpoint, and the difference signal is conditioned by a three-mode algorithm. The resultant output is passed to the weigh feeder controller as a derived setpoint. The weigh feeder control works with a cascade secondary and utilizes the mass-flow measurement as its process variable. The control output is proportional to the material flow rate, which is required for the weigh feeder.

A synopsis of this Melt Unit Fill Level control loop operation is:

- Melt unit level far below setpoint
  - output of cascade primary loop large
  - derived setpoint of cascade secondary loop high
  - output of secondary loop high
  - weigh feeder speed maximum

- Melt unit in range, below, but approaching setpoint
  - output of cascade primary loop reducing, rate of change depending on rate of melt unit level increase

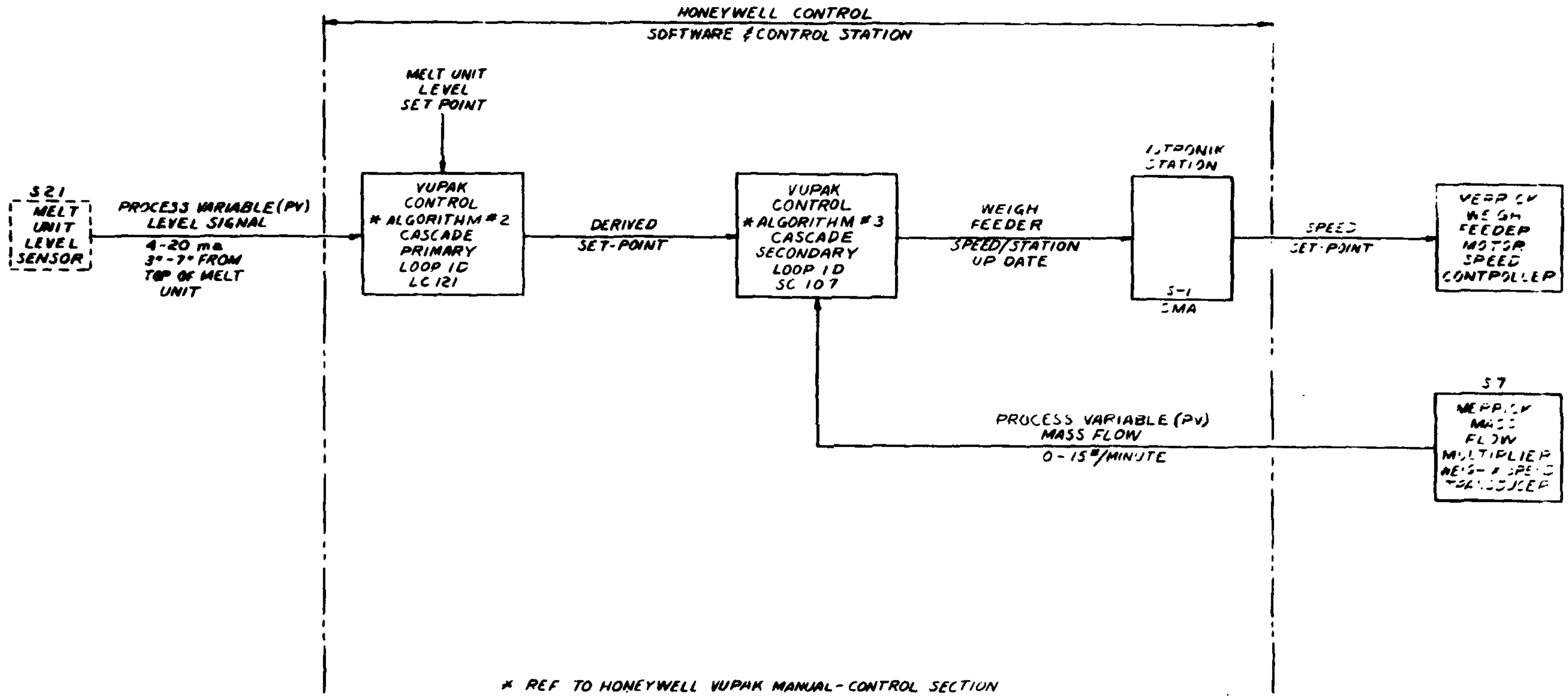


Figure 3-7. Weigh Feeder/Melt Unit Level Cascade Control

- derived setpoint of cascade secondary loop reducing
- output of secondary loop reducing
- weigh feeder speed reducing

. Melt unit liquid level at setpoint

- output of cascade primary loop stable
- derived setpoint of cascade secondary loop stable
- output of secondary loop stable
- weigh feeder speed stable

. Melt unit liquid level above setpoint

- output of cascade primary loop reducing or increasing, depending on whether the primary process variable is approaching or departing from the setpoint value
- derived setpoint follows the primary cascade loop output
- output of secondary cascade loop seeks null via comparing its setpoint to the mass flow process variable
- weigh feeder speed seeks stable operating point

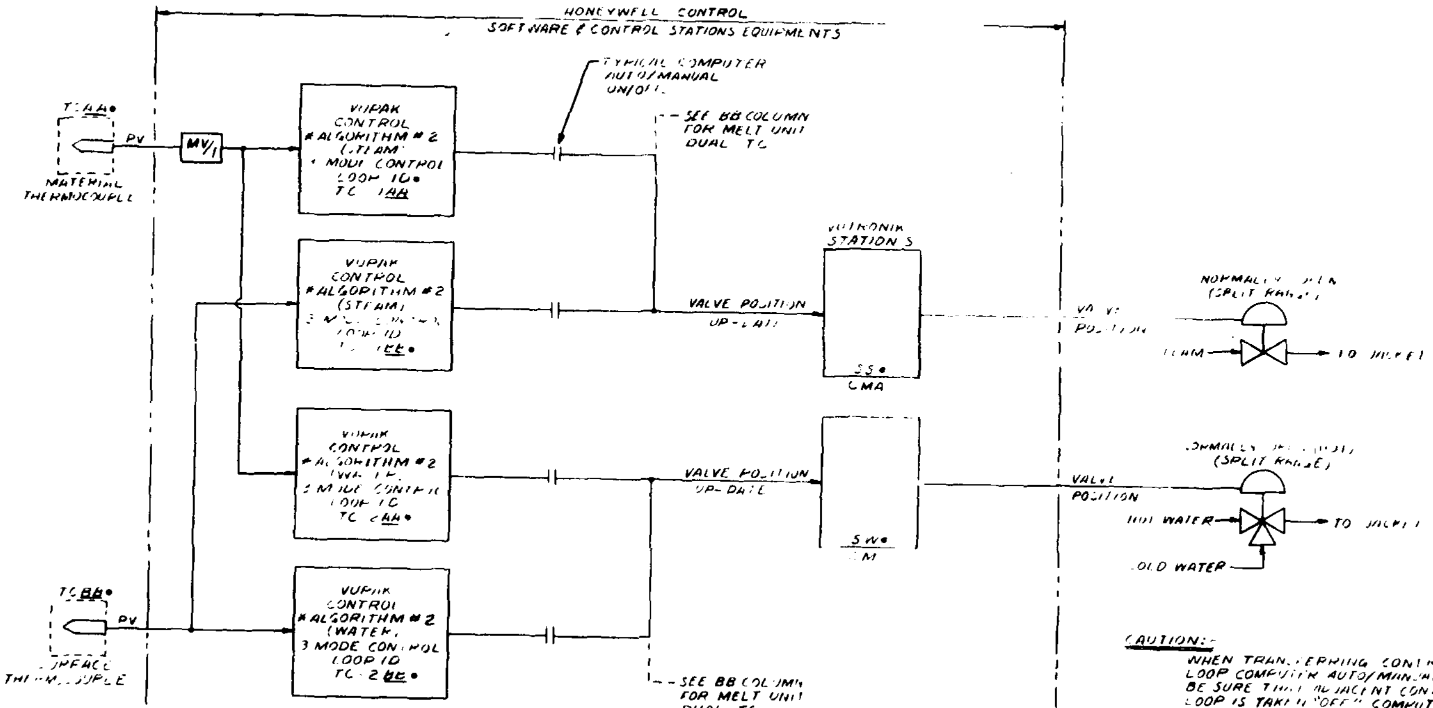
Obviously, the condition described third is the desired control point, and the tuning of this control loop is oriented toward achieving this stable operation.

4) <u>Melt Unit, Product Piping, and Pump Heating</u> - The heat control of the Melt Unit, product piping, and pump are identical; therefore, they will be described together. Pipe heat control has been broken into small sections established to accommodate the physical placement of the piping and its functional application. For the purpose of this analysis, two sections are established: 1) the pipe between the melt unit and the pump; 2) the pipe section that follows the pump up to the valving for recycle/pour and the pipe between the recycle valve back to the melt unit. The melt unit and pump are individual heat control sections. The control objective for each of these heat sections is to maintain a stable product temperature at the operating setpoint.

To permit maximum flexibility of pilot plant operation, heating the melt unit, product piping sections and pump is operator-selectable for either steam or hot water heatant. Refer to Figure 3-8. The control action is quite elementary. The temperature of the material being heated is measured, and that value is taken as the process variable. The system has a setpoint either from its programmed data base or from the operator's entry at the console. The process variable is compared to the setpoint, and the error signal is fed into a three-term algorithm. The control output is used to modulate the heatant valve, thus closing the loop.

TABLE
SENSOR/STATION
ASSIGNMENTS

	AA	BB	SS	SW
MELT UNIT			DUAL	
TOP	[illegible]	[illegible]	[illegible]	
MIDDLE	[illegible]	[illegible]	COUPLE	
BOTTOM	13	[illegible]	NO MV/D	
SURFACE	—	(71)	[illegible]	4
PUMP	65	[illegible]	5	[illegible]
PIPE LOOP #1	23	(72)	8	9
PIPE LOOP #2	[illegible]	(73)	10	11
PIPE LOOP #3	35	(74)	12	13
▲ PIPE LOOP #4	37	(75)	14	15
PIPE LOOP #5	39	(75)	16	17
▲ PIPE LOOP #6	41	(75)	18	19
PIPE LOOP #7	43	(76)	20	21



* REF HONEYWELL VUPAK MANUAL-CONTROL SECTION

CAUTION:-
WHEN TRANSFERRING CONTROL LOOP COMPUTER AUTO/MANUAL BE SURE THAT ADJACENT CONTROL LOOP IS TAKEN "OFF" COMPUTER CONTROL BEFORE ANY LOOP IS PLACED "ON" COMPUTER CONTROL

NOTE:
REF. HONEYWELL CORPORATE PROGRAM CENTER DWG. NO F9033-01-005

NOTES:-
▲ PIPE LOOPS #4 [illegible] SAME SURFACE THERMOCOUPLE [illegible] PIPE LOOP #5 [illegible] SIGNIFICANT DIGIT [illegible] BE [illegible] FOR STEAM AND EVEN [illegible] WATER
THUS: PIPE LOOP #4 [illegible] SURFACE TC 375/ MATERIAL: TC 475
PIPE LOOP #6 [illegible] SURFACE: TC 575/ MATERIAL: TC 675
• REF TO TABLE SENSOR/STATION ASSIGNMENTS

Figure 3-8. Melt Unit Pump and Pipe Loops Temperature Control

5) <u>Pump Stroke Control</u> - To adjust the volume of material delivered by the explosive pump, a pump stroke control transducer is provided. The objective of this control function is to achieve the desired explosive quantity flow while not exceeding pressure limits at any of the test points.

Control of this parameter is accomplished by measuring the pressure P-88 and using it as a process variable. This is compared to a programmed setpoint and the error signal drives the control output to null the error. (See Figure 3-9.) Data acquisition points at the pressure test points can reduce the setpoint for this pump stroke control loop if they identify a pressure which is out-of-limits.

6) <u>Position Control of Recycle/Pour Valves PV-6 and PV-8</u> are proportional control elements that direct the molten explosive either to the pouring sytem or back to the melt unit for recycle. The control objective of these valves is to deliver material to the pouring area when it is demanded or otherwise recycle it back through the melt unit.

Supervisory control is used for this pair of loops. (See Figure 3-10.) The valve position setpoint is fed into the controller from either the operator at his console or from the sequence control program. This supervisory algorithm simply takes the setpoint and responds with a control output. No process variable is considered to determine the output of this algorithm.

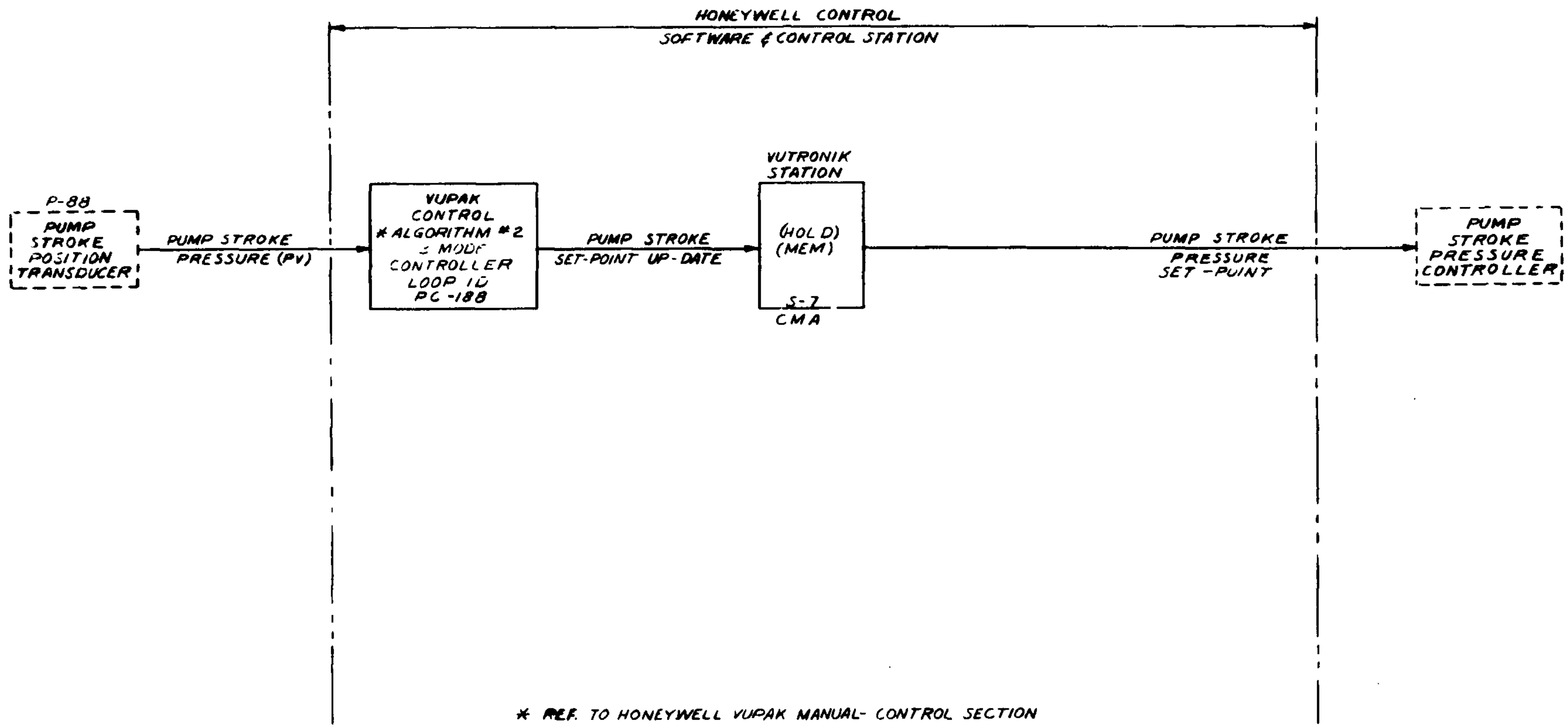


Figure 3-9. Pump Stroke Control

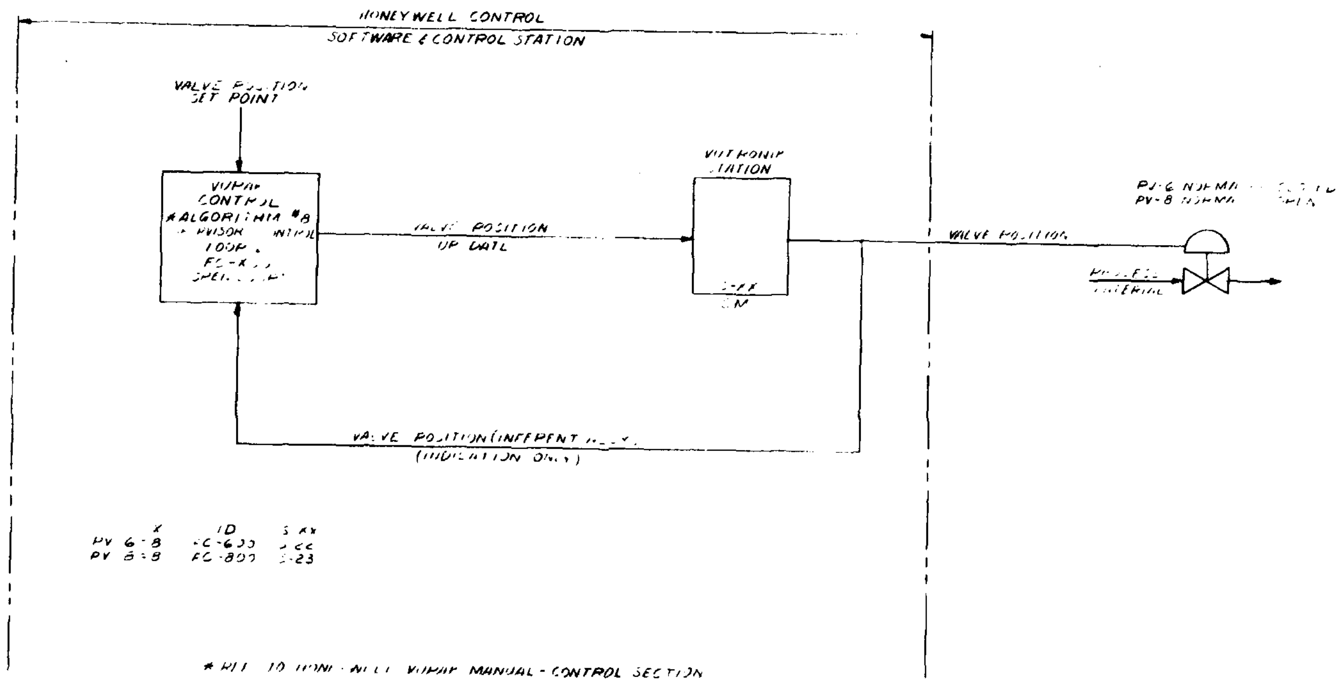


Figure 3-10. Manual Loading for PV6 and PV8 Process Flow Proportioning Valves

Fail-safe design is incorporated into each of the foregoing control functions. For each function in which a loss of control is deemed safe while held at preprogrammed high temperature, the system is designed to fail in that mode; for those functions in which loss of control is deemed safe while they are cooled to ambient, the system fails in that manner. For those parameters which require continued setpoint control in all conditions, automatic backup to the computer control has been provided. This later feature is accomplished via self-checking of the computer operation and commanding the control stations to operate local-automatic in the event of computer failure.

7) Melt Unit Agitator Speed Control - To facilitate remote control of the melt unit agitator speed, which is propelled by a hydraulic motor, a variable position valve is located in the line between the pump and the motor. This valve may be driven in either direction -- more open or more closed -- thus affecting the agitator speed. Also, the agitator shaft is equipped with an encoder which transmits the rotational speed of the agitator. The objective is to control the agitator to a setpoint speed. The setpoint may be either operator-selected at his console or preprogrammed in the sequence control programs.

Control is a straightforward, closed loop control of the speed control valve. (See Figure 3-11.) The agitator speed is acquired -- compared to the setpoint -- developing an error signal operate on the error signal with a three-term algorithm -- and give a control output to position the speed control valve.

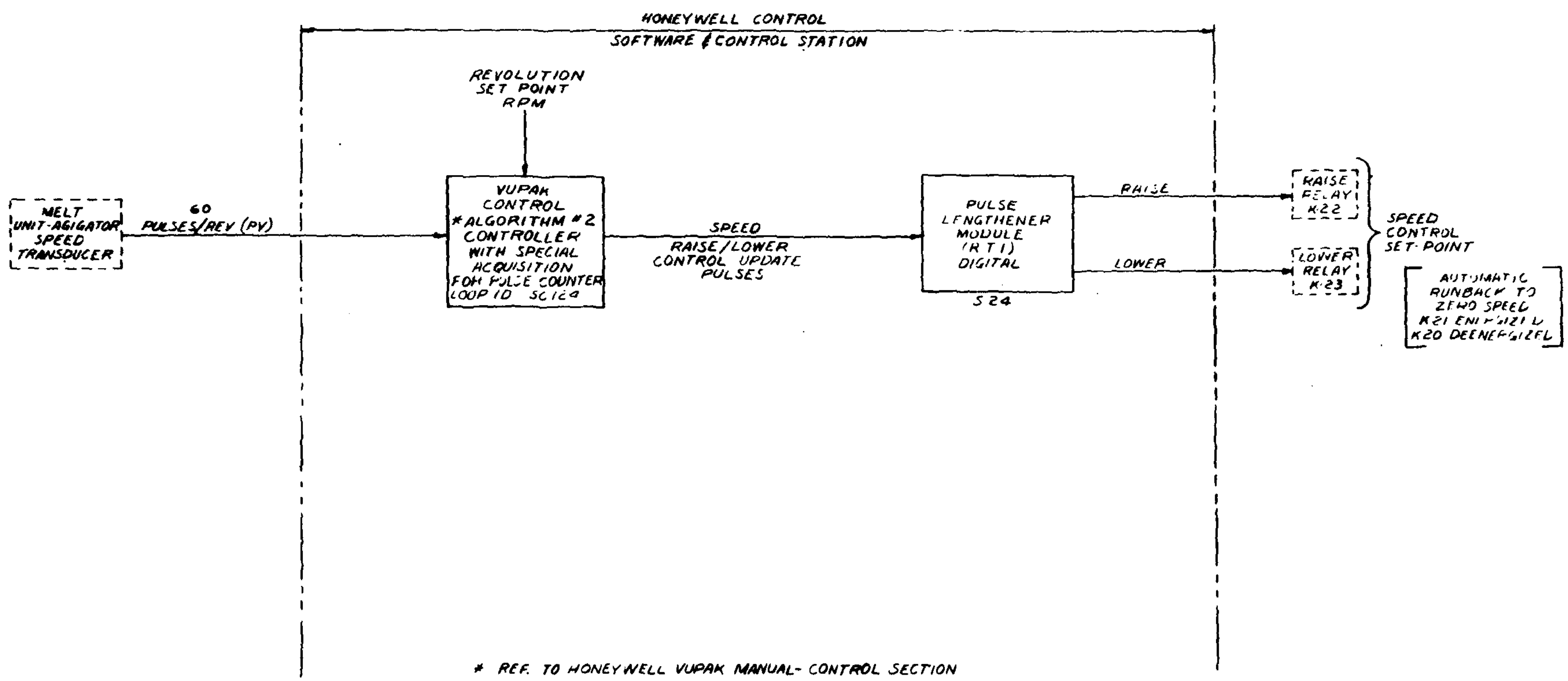


Figure 3-11. Melt Unit, Agitator Speed Control

8) <u>Digital INPUT/OUTPUT Functions</u> for process control include the on-off items, such as:

a) operator presence signal from the Inspection Building

b) load conveyor indicator light in the Inspection Building

c) start or stop explosive pump in the Melt/Pour Building

d) open or close the two-position valves, such as PV-1 and PV-4

e) operate the system purge network valves, such as CV-1, -2, -3, -4, -5, -6, and PV-5, -7, -3, -10.

The objective in manipulating each of these devices is to permit automatic (or remote manual) control of the Continuous Melter System's two state control elements.

Actuation (or data acquisition) of all the listed two state devices is achieved via remote automatic on-off control from the system's control computer. For the data acquisition portion, signal inputs of this category are scanned on a regular interval of once each second. The status of each element is monitored to see if it has changed during the interval, and all subsequent control actions are initiated if it has. For the output functions, the updating of their status is also done periodically (once per second). If the operating program requires a change in the state of an output, or if the operator requests a change in the output state, that selection is processed at the next clock interval, and the outputs are revised accordingly.

9) Digital INPUT/OUTPUT Functions for Safety Control include the on-off items, such as:

a) fire alarm sensor

b) utility interlock sensor

c) conduit pressurization sensor

d) weigh feeder motor housing pressurization sensor

The control objective for accomplishing the actions demanded by these signals is to take immediate action.

The inputs itemized above are connected to the signal terminal that creates a computer interrupt when the signal is received. These interrupts are serviced in order of priority and the attendant control actions are commanded. Also, the system operator has a high priority interrupt switch labeled EMERGENCY STOP. If he presses this switch, the system immediately goes to the Emergency Stop state and awaits the operator's next command.

10) Remote Process Monitoring, Data Logging, and Operator Control Actions are necessary functions for operation of the Continuous Melter System. The quipments for these functions are located in the Control Building.

Computer-to-computer communication has been established between the Process Control System located in juxtaposition to the main process building and the Operator Monitor System in the Control Building. All the operating data is transmitted regularly at fifteen-second intervals

from the process area to the monitor area. Operator adjustments to the process are transmitted to the process area as he enters them. Permanent logging of all operating data is done on magnetic tape for later analysis or storage. Visual display of the system operation is done via a pictorial wall display which has alphanumeric displays of all the critical process data. The operator has a console at which he can monitor or adjust the process control operation via keyboard entry. An alarm typer is provided to record on paper all system mode changes, operator commands, and process alarm states with the time of day printed beside each annunciation.

COST ESTIMATE FOR CONTINUOUS MELTER CONTROL SYSTEM

To estimate the cost of the Continuous Melter Production Control System the general control configuration shown in Figures 3-12 and 3-13 is used as a baseline.

The control system equipment list for the process control system is itemized in Tables 3-1 and 3-2.

The control system equipment list for the process monitor system is itemized in Table 3-3.

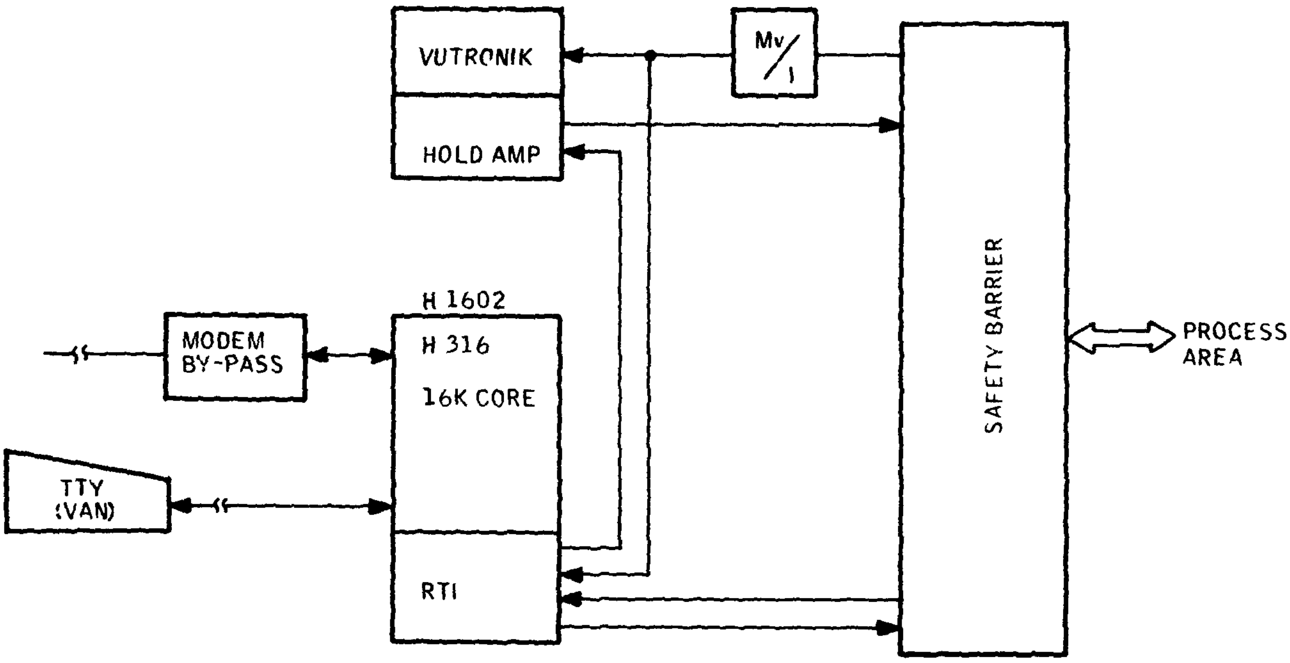


Figure 3-12. General Process Control Configuration

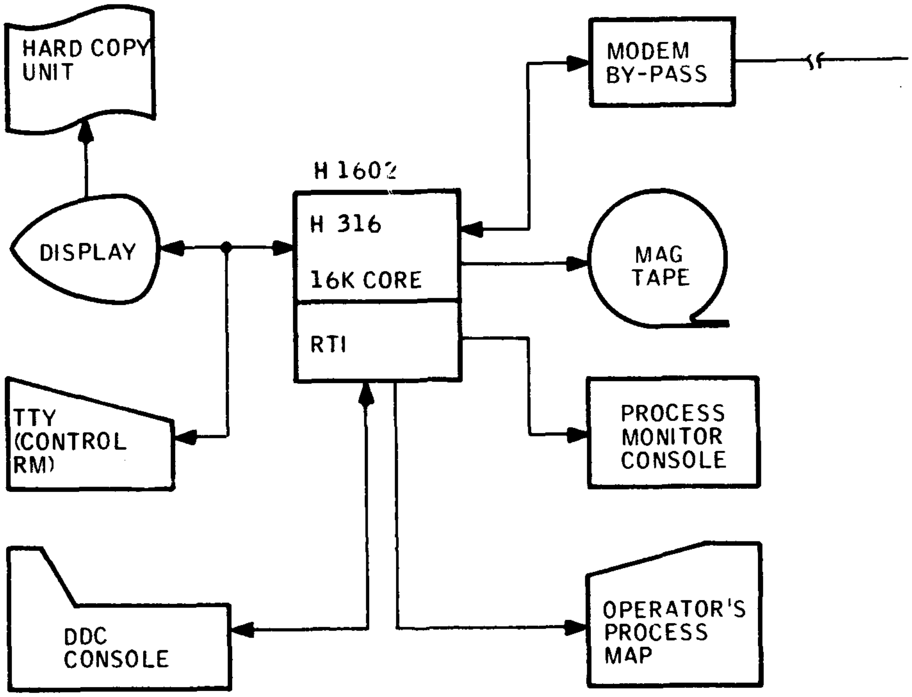


Figure 3-13. General Process Monitor Configuration

Table 3-1. Continuous Melter Process Control Computer Equipment List

QUANTITY	MODEL	DESCRIPTION
1	1602-01	H1602 Real-Time Control
3	1602-02	Additional 4K Core Modules
1	316-0800	Base Sector Relocation
1	316-6000	Data Line Controller
1	316-6006	DMC Sub-Channel
1	1602-11	High Speed Arithmetic
1	1602-6925	Modem By-Pass
1	316-20	Direct Multiplex Control
1	1621-07	Cyclic Redundancy Check
1	1602-8611	Analog Master - Page A
2	1602-8642	MUX, High Level Differential
2	1602-8634	MUX, Low Level T/C
1	1602-8676	Isothermal Units, 30 T/C Inputs
1	1602-8653	Amplifier, 100 mv
1	1602-8657	Amplifier, 10 v
2	1602-8581	Customer Connections, Analog
3	1602-8731	Status Inputs PACs (contact)
1	1602-8811	DDC Station Controller
3	1602-8831	Power Flip-Flop
1	1602-8861	Relay Output Module
1	1602-8721	+24V, 6A Power Supply
3	1602-8580	Customer Connections, Digital
1	1602-8761	Event Counter
1	1602-8741	Async Input PAC, Contact
1	1602-8541	Watchdog Timer and #1 Timing Chain

Table 3-2. Continuous Melter Process Control Analog Equipment List

QUANTITY	MODEL	DESCRIPTION
4	36686-3063-0100-512-000-51	VutroniK DDC Stations
6	36689-3063-0100-000-51	VutroniK Stations
13	39511-4060-111-51-72	MV/I Transmitter
1	38582-2010-0000-000-72	Power Supply, 7 amp
2	37800-2060-0000-000-000-72	Multi-U nit Case
36	38545-0000-0110-111	Barrier Points, Positive
36	38545-000-0110-112	Barrier Points, Negative
16	ELA 3271	Kent Barriers
18	870022-112-11-13-01-00-72	E/P Transducers

Table 3-3. Continuous Melter Process Monitor System Equipment List

QUANTITY	MODEL	DESCRIPTION
1	1602-01	H1602 Real-Time Control System
2	1602-02	Additional 4K Memory Modules
1	1602-6925	Modem By-Pass
1	1602-11	High Speed Arithmetic Module
1	316-6000	Data Line Controller
1	316-6006	DMC Sub-Channel
1	1602-20	Direct Multiplex Control
1	1621-07	Cyclic Redundancy Check Module
4	1602-8580	Customer Connection, Digital
1	316-5303	ASR-33 TTY With Interface
2	1602-8851	Universal Output Flip Flop PAC
3	1602-8732	Status Input PAC
1	1602-8852	Universal Output Single Shot PAC
1	1602-8831	Power Flip Flop Output PAC
1	1602-8742	Asynchronous Input PAC
1	1602-8721	+24V Power Supply
1	1602-8541	Watchdog Timer and #1 Timing Chain
1	96-02-02	DDC Operator's Console
1	Special	Operator's Process Map
1	Special	Process Monitor Console

Cost of these items are as follows:

1)	Systems Engineering and Software Development	$ 65,000
2)	Process Control Computer Equipments	36,100
3)	Process Control Analog Equipments	20,000
4)	Process Control Equipment Installation	8,600
5)	Process Control Interface Wiring	13,500
6)	Intercomputer Communication Wiring	3,500
7)	Process Monitoring Equipments	55,000
8)	Process Monitoring Equipment Installation	6,500
9)	Total System Debug and Demonstration	26,000
		$234,200

ESTIMATED COST FOR CONTINUOUS MELTER CONTROL SYSTEM	$234,200
ESTIMATED COST FOR ON-CALL MAINTENANCE OF CONTINUOUS MELTER SUBSET CONTROL SYSTEM (PER MONTH)	1,160

SECTION IV

FINDINGS

The present study concentrated on the control system aspects of the two explosives melting processes. It did not address the relative merits of one process against the other, nor did it evaluate those process characteristics related to meeting product specification requirements for the various projectiles that represent the end product of a melt/pour line. The following observations deal exclusively with the conceptual automatic control systems configured for each of the two explosive melting processes.

CONCLUSIONS

The stage of development for the Minute Melter has not yet reached the level of the Continuous Melter. This makes it convenient to contrast the two conceptual control systems described in this report with the existing ICMS, as installed at Picatinny Arsenal's pilot plant.

Continuous Melter Control System

The control system for a Continuous Melter production plant will, in some respects, be simpler than the ICMS for the pilot plant, where R & D needs and redundant alternative means of monitoring and control had to be evaluated.

The Continuous Melter Process includes fewer pieces of process equipment. This reduces the number of instruments and control loops required for the

automatic remote control operation of the explosive melting portion in a LAP plant.

The software developed, debugged, and installed in the ICMS at the pilot plant will require only some easily implemented modifications to adapt it to the envisioned production plant.

Under these circumstances, the efforts and resources required to design, fabricate, install, and commission the automatic remote process control system for the Continuous Melter Process will be smaller in magnitude and of shorter duration than for the Minute Melter Process. Most of the difficult work has already been completed under the auspices of the ICMS program. This is reflected in the cost estimates, as reflected in the discussion in Section IV.

Minute Melter Control System

The capability of handling both flake explosive and riser scrap in the Minute Melter Process requires proper ratio control in feeding the solid explosive in order to meet the end-item specification requirements for each of the rounds under consideration. This capability necessitates extra process instruments and control loops in the system.

The separate pieces of equipment required for melting and for conditioning the molten explosive prior to pouring must be provided with individual sensors and controls for both the controlled process variables and the manipulated variables. Thus, the scope of the control system problem is more extensive.

Not only the number of instruments, but also the measuring process makes the control system design task more difficult. Offhand, one cannot identify a single moisture sensor that can reliably and safely measure the moisture (water) content within the hot explosive slurry (solid RDX, molten TNT, plus water in the form of saturated or condensed steam) inside of the explosive final conditioning units. At present, moisture content is estimated on the basis of temperature readings over time for the vacuum conditions affecting the slurry as it is reheated in the final conditioner unit.

Since the software for this semi-continuous Minute Melter process will differ from the existing ICMS software package, the cost estimate for the Minute Melter alternative must include the necessary development, debug, and installation efforts.

From these points of view regarding hardware, software, and system integration costs, it appears that the Continuous Melter option is the less costly and less risky implementation alternative as far as the automatic control system is concerned.

RECOMMENDATIONS

The Continuous Melter Control System alternative offers a number of significant benefits:

1) The system is simpler.
2) The system has a proven track record, and
3) The system software has already been generated.

Based on these factors, one can base predictions concerning the reliability and safety potential of this control system alternative on actual operating experience. Since the Minute Melter alternative has not yet reached this developmental stage, the Continuous Melter Control System approach presents less of a developmental risk, both in terms of funding required and time span involved. To furnish a melt operation control system based on the Continuous Melter into the hands of the user plants at an early date, it is recommended that the following actions be initiated:

- Commence design of a computer-based automatic remote control process control system for a full-scale loading plant installation patterned after the ICMS.

- Simplify the production--plant melter control system as compared to the pilot plant system with its additional requirements aimed at R & D functions.

- Eliminate the multiple sensing and monitoring provisions for the same process variable by retaining the most reliable control loop based on pilot plant results.

- Retain the basic control system approach incorporated in the ICMS configuration with its five control functions for the five operational modes for the melt/pour plant.

REFERENCES

1. First Interim Report, Hazards Analysis for Melt/Pour Follow-On System, Allegheny Ballistics Laboratory, Sept. 1974

2. Instrumentation Control and Monitoring System (ICMS)

    Vol. 1 - System Description

    Vol. 2 - Hardware Description

    Vol. 3 - Software Description

    Vol. 4 - System Support Manuals

    R. Satz, Technical Support Directorate, Picatinny Arsenal

3. Instrumentation Control and Monitoring System (ICMS) for the Melt/Pour Pilot Plant (MPPPP)

    Vol. 1 - Systems Manual

    D. Morlock, Technical Support Directorate, Picatinny Arsenal

APPENDIX A

MINUTE MELTER SAFETY CONSTRAINTS

MINUTE MELTER SAFETY CONSTRAINTS

- Amount of "flake" Composition B, Riser Scrap, and Molten Explosive entering
  - hoppers
  - interlock hoppers
  - melter
  - conditioners

  to stay within quantity limits for each location, prevent double feeding, and minimize propagation of detonation in an incident.

- Maximum Explosive Temperature Reached
  - by risers in its interlock hopper
  - by flake in its interlock hopper
  - by mixed explosive in melter and in conditioners

  (as a function of steam pressure, time, and height of explosive layer, to mention major factors).

- Interlocks Between Process Team (Contacting HE)/Jacket Steam and
  - rotator of Minute Melter
  - rotator of conditioners
  - level controls in Melter

- Interlocks Between Draw-Off Line Valves, and
    - process steam in melter
    - air pressure in conditioner
    - vacuum in conditioner

- Interlocks between flapper valves in
    - flake hopper
    - flake interlock hopper
    - riser hopper
    - riser interlock hopper

AND: Valves Controlling Process (Contact) Steam in

- melter
- riser interlock hopper

ALSO: Draw-Off Valve (From Melter to Conditioner)

APPENDIX B

INSTRUMENT LIST

FOR

AUTOMATIC REMOTE CONTROL

OF

MINUTE MELTER SYSTEM

INSTRUMENT LIST FOR AUTOMATIC REMOTE CONTROL OF MINUTE MELTER SYSTEM

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
1 --				
FLAKE FEEDER	PC -	1-1	Vacuum Collector Control	Senses Suction, Interlocked with Conveyor Drive
	M -	1-1	Conveyor Drive	Motor On/Off Control, Interlocked with Hopper Level
	LTH -	1-1	Hopper Level (High) Transmitter	Shut Off Feed Conveyor
	LTL -	1-2	Hopper Level (Low) Transmitter	Start Feed Conveyor
	WT -	1-1	Weigh Feeder Load Sensor	Transmit Weight to Find Rate Using Speed Sensor
	M -	1-2	Weigh Feeder Drive	Motor On/Off With Variable Speed Control
	ST -	1-1	Weigh Feeder Speed Sensor	Derive Feed Rate From Driven Speed and Weight
	FV -	1-1	Flow Valve	Shut Off Feed Duct Between Feeding Steps

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
2 --				
RISER FEEDER	M -	2-1	Conveyor Drive	Motor On/Off Control, Interlocked with Hopper Level
	LTH -	2-1	Hopper Level (High) Transmitter	Shut Off Feed Conveyor
	LTL -	2-2	Hopper Level (Low) Transmitter	Start Feed Conveyor
	WT -	2-1	Weigh Feeder Load Sensor	Transmit Weight to Find Rate Using Speed Sensor
	M -	2-2	Weigh Feeder Drive	Motor On/Off With Variable Speed Control
	ST -	2-1	Speed Sensor of Weigh Feeder	Derive Feed Rate from Driven Speed and Weight

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
3 --				
RISER INTERMEDIATE HOPPER	FV -	3-1	Input Feed Valve	Admit Risers, Seal Hopper During Preconditioning
	TIC -	3-1	Temperature Indicating Control	Maintain temperature corresponding to 15 PSIG Steam (Max.) for Riser Preconditioning
	TIC -	3-2	Temperature Indicating Control	Maintain Jacket Heat at Temperature Corresponding to 18 PSIG Steam (Max.) for Riser Conditioning
	FV -	3-2	Output Feed Valve	Release Preconditioned Risers to Melter; Seal Off Hopper/Melter at Other Times

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
4 --				
FLAKE INTERLOCK HOPPER	M -	4-1	Feed Auger Drive	Air Motor On/Off With Variable Speed Control
	ST -	4-1	Feed Auger Speed Sensor	Drive Feed Rate (for Flake/Riser Ratio Control)
	LTL -	4-1	Feed Hopper Low Level Sensor	Stop Auger Drive
	FV -	4-1	Input Feed Valve	Admit Flake to Interlock Hopper, Seal Hopper During Flake Preconditioning
	TIC -	4-1	Temperature Indicating Control	Maintain Jacket Stem Heat at Preconditioning Level for Flake Present
	PIC -	4-1	Pressure Indicating Control	Provide and Maintain Air Pressure During Feeding of Preconditioned Flake Into Melter
	FV -	4-2	Output Feed Valve	Release Preconditioned Flake from Interlock Hopper to Melter; Seal During Preconditioning

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
5 --	TIC -	5-1	Temperature Indicating Control	Maintain Jacket Steam Heat at Melt Level (Corresponding to 18 PSIG Max.)
	TIC -	5-2	Temperature Indicating Control	Maintain Process Heat (Direct Contact of Steam with Explosive) (Corresponding to 15 PSIG Max.)
	LTH -	5-1	High Level Sensor	Solid Explosive Level Inside Drum
	LTH -	5-2	High Level Sensor	Molten Explosive Level Between Drum & Enclosure
	LTL -	5-3	Low Level Sensor	Molten Explosive and "Heel"
	LTL -	5-4	Low Level Sensor	Solid Explosive Level Inside Drum
	M -	5-1	Drum Rotator Drive	Motor On/Off with Variable Speed Control, Interlocked with TIC-5-1 and -2 and Level Indicators
	ST -	5-1	Speed Sensor For Drum	Cut Heat if Drum Rotation Stops (Prevent Critical Heating of Explosive via Interlocks with TIC-5-1 & -2)
	T -	5-1	Contaminated Condensate Trap	Collect Steam Condensate from Minute Melter (Containing Small Amounts of H.E.)
	LC -	5-5	Level Control for Trap	Keep Trap Contents Between High and Low Levels by Discharging Liquid to Collector Via Heated Pipes

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
6 --				
DRAW-OFF FROM MELTER (To Conditioners)	TIC -	6-1	Temperature Indicating Control	Maintain Jacket Steam Heat (18 PSIG Max.)
	TT -	6-2	Temperature Sensor(s)	Redundant Transmitters for Multiple Draw-Off Line Legs
	FV -	6-1	Flow-Control Diaphragm Valve	Draw-Off of Molten Explosive from Melter to Conditioner #1
	FV -	6-2	Flow-Control Diaphragm Valve	Draw-Off of Molten Explosive from Melter to Conditioner #2

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
7 --				
FINAL CONDITIONER NO. 1	PIC -	7-1	Pressure Indicating Control (Air)	Pressurizing Conditioner to Transfer Conditioned Explosive to Pouring Machine
	TIC -	7-1	Temperature Indicating Control	Maintain Jacket Steam Heat for Vacuum Line (to Prevent Solidification)
	TIC -	7-2	Temperature Indicating Control	Maintain Conditioner Jacket Steam Heat During Conditioning Cycle
	PIC -	7-2	Pressure Indicating Control	Maintain Vacuum Conditions as Called For by Conditioning Cycle
	LTH -	7-1	High Level Sensor	High Limit During Filling with Molten H.E.
	LTL -	7-2	Low Level Sensor	Low Limit During Draw-Off After Conditioning H.E.
	M -	7-1	Drum Rotator Drive	Motor On/Off, with Variable Speed Control, Interlocked with TIC-7-2
	ST -	7-1	Speed Sensor For Drum	Stop Heat if Drum Rotation Stops (Prevent Critical Heating of H.E. Via Interlocks with Heat and Level Controllers)

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
8 -- POURING DRAW-OFF	TIC -	8-1	Temperature Indicating Control (water)	Maintain Jacket Hot-Water Heat
	TT -	8-2	Temperature Sensor(s)	Redundant Transmitters for Multiple Draw-Off Line Legs
	FV -	8-1	Flow-Control Diaphragm Valve	Molten Explosive Draw-Off From Conditioner to Pcuring Machine (Ist Conditioner)
	FV -	8-2	Flow-Control Diaphragm Valve	Molten Explosive Draw-Off From Conditioner to Pouring Machine (Conditioner No. 2)

ZONE NO.	INSTRUMENT I.D. FUNCTION	INSTRUMENT I.D. LOOP NO.	DESCRIPTION	FUNCTION OR CONDITION
9 --				
FINAL CONDITIONER NO. 2	LTH -	9-1	High-Level Sensor	High Limit During Filling with Molten H.E.
	LTL -	9-2	Low-Level Sensor	Low Limit During Draw-Off After Conditioning H.E.
	M -	9-1	Drum Rotator Drive	Motor On/Off with Variable Speed Control, Interlocked with TIC-9-2
	ST -	9-2	Speed Sensor For Drum	Stop Heat if Drum Rotation Ceases (Prevent Critical Heating of H.E. Via Interlocks with Heat and Level Control.
	TIC -	9-1	Temperature Indicating Control	Maintain Jacket Steam Heat for Vacuum Line (to Prevent Solidification)
	TIC -	9-2	Temperature Indicating Control	Maintain Conditioner Jacket Steam; Heat During Conditioning Cycle
	PIC -	9-1	Pressure Indicating Control (Air)	Pressure Conditioner to Transfer Explosive to Pouring Machine
	PIC -	9-2	Pressure Indicating Control (Vacuum)	Maintain Vacuum Conditions as Called for By Conditioning Cycle